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# CONTENTS

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# FISHERY TRENDS IN RESERVOIRS OF SAN DIEGO COUNTY, CALIFORNIA, FOLLOWING THE INTRODUCTION OF FLORIDA LARGEMOUTH BASS, *MICROPTERUS SALMOIDES FLORIDANUS*[1]

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**The impact of Florida bass introductions in four San Diego County, California reservoirs (El Capitan, Sutherland, San Vicente, and Lower Otay), was evaluated from 1965 through 1976. Florida bass hybridized with resident northern stocks in all test waters. Bass populations rapidly assumed Florida-like characteristics at Sutherland and Lower Otay reservoirs and a similar, although less complete, transition occurred at San Vicente Reservoir. By contrast, the bass population at El Capitan Reservoir has remained in a comparatively stable hybridized state for a number of years. Northern bass grew slightly faster than Florida bass during their first year of life. In subsequent years, Florida bass grew at substantially faster rates. Florida bass are less vulnerable to angling than northern or hybrid bass and populations with Florida-like characteristics are resistant to overharvest by anglers. The mean size of bass caught and the incidence of trophy specimens has increased in reservoirs where Florida bass have been established. Increased bass yields were associated largely with the development of hybridized populations although one impoundment containing bass with Florida-like characteristics provides angling of exceptional quality. Bluegill yields have declined markedly in reservoirs where Florida bass were introduced.**

## INTRODUCTION

Opportunities for inland angling in metropolitan southern California are provided largely by a series of small and medium-sized reservoirs designed to help meet the areas' need for irrigation and domestic water supplies. A few such reservoirs provide angling for rainbow trout, *Salmo gairdneri,* while the majority support an assemblage of warmwater fishes usually dominated by largemouth bass, bluegill, *Lepomis macrochirus,* crappie, *Pomoxis spp,* and catfishes, *Ictalurus spp.* Southern California reservoirs are noted for their high fish production under conditions of intense fishing pressure (McCammon 1953, Beland 1960, La Faunce, Kimsey, and Chadwick 1964).

Northern largemouth bass, *M. s. salmoides,* originally imported from Illinois in 1891 (Shebley 1917), have historically comprised an important segment of these reservoir fisheries. Despite high overall fish production, however, northern bass have sometimes been unable to control other centrarchid species. Bluegill, particularly, often display a tendency to develop large, slow-growing populations which are lightly utilized by anglers. Management efforts, therefore, have centered largely on the development of methods for increasing bass abundance and improving the growth characterictics of bluegill populations (Bell 1959, Beland 1960, Fast 1966).

At the request of the San Diego County Fish and Game Commission and the City of San Diego Utilities Department, a decision was made to import Florida largemouth bass, *M. s. floridanus,* on an experimental basis. This decision was

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based on (i) the large size, rapid growth, and overall sporting qualities of bass in Florida and (ii) the possibility that Florida bass would be better adapted than the northern strain to environmental conditions in southern California. Ultimately, it was hoped that the introduction of Florida bass would improve the quality of bass angling in terms of numbers and sizes of fish taken and that bluegill populations would be more effectively controlled.

In May 1959, a shipment of 20,400 fingerling Florida largemouth bass was received from Holt State Fish Hatchery near Pensacola, Florida. These fish were liberated into Upper Otay Reservoir, San Diego County, which had been chemically treated to eradicate all fish. (Sasaki 1961). A self-sustaining population soon became established and Upper Otay Reservoir (which is closed to public angling) later served as a brood source for Florida bass introductions into additional waters. San Diego County impoundments initially stocked with Florida bass include Lower Otay Reservoir, Sutherland Reservoir, and Lake Wohlford in 1960 and Lake Miramar and El Capitan Reservoir in 1961. With the exception of Lake Miramar, these impoundments contained established warmwater game fish populations (including northern largemouth bass) at the time these introductions were made.

Beginning in 1965, a study was designed to assess the overall impact of Florida bass introductions on the fisheries of several San Diego County impoundments. This report summarizes the results of this investigation and considers: (i) changes in the meristic characteristics (lateral line scale counts) of bass populations at El Capitan, Lower Otay, San Vicente, and Sutherland reservoirs; (ii) the growth characteristics of Florida bass, northern bass, and their hybrids at El Capitan Reservoir; (iii) the vulnerability to angling of Florida, northern, and hybrid bass at El Capitan, Sutherland, and Lower Otay reservoirs; and (iv) trends in angling quality attributable to Florida bass introductions at Sutherland and El Capitan reservoirs.

## DESCRIPTION OF STUDY RESERVOIRS

Waters selected for study are currently operated for nonwater contact activities by the City of San Diego Department of Parks and Recreation (Lakes Division). All are open to public angling and receive intense fishing pressure. They serve primarily as domestic water supply impoundments and feature spring and summer drawdowns ranging from 1.5 to 4.0 m (5 to 13 ft) at Sutherland Reservoir to 6.1 to 7.6 m (20 to 25 ft) at El Capitan Reservoir. Surface area at full pool ranges from a low of 226 ha (557 acres) at Sutherland Reservoir to a high of 632 ha (1,562 acres) at El Capitan Reservoir. With the exception of Sutherland Reservoir at a surface elevation of 627 m (2,057 ft), all impoundments are located at elevations below 244 m (800 ft). These reservoirs characteristically do not fill each year and storage at mean pool is often a minor fraction of total reservoir capacity (Table 1).

**TABLE 1. Physical Characteristics of Test Reservoirs**

| *Physical parameter* | | *Sutherland* | *San Vicente* | *Lower Otay* | *El Capitan* |
|---|---|---|---|---|---|
| Completion of dam | | 1953 | 1943 | 1919 | 1934 |
| Drainage* area ($km^2$) | | 137 | 194 | 254 | 264 |
| Surface elevation (m) | | 627 | 198 | 150 | 229 |
| Surface area (ha) | Full pool | 226 | 433 | 497 | 632 |
| | Mean pool | 81 | 283 | 121 | 225 |
| Storage capacity ($hm^3$) | Full pool | 36.6 | 111.3 | 69.7 | 139.1 |
| | Mean pool | 5.3 | 4.0 | 7.4 | 23.3 |
| Maximum depth (m) | Full pool | 44 | 58 | 44 | 60 |
| | Mean pool | 22 | 49 | 20 | 31 |
| Normal annual fluctuation range (m) | | 1.5–4.0 | 4.6–7.6 | 1.8–4.6 | 6.1–7.6 |

* All reservoirs except Sutherland periodically receive water from the Colorado River Aqueduct.

## METHODS

### Lateral Line Scale Counts

Lateral line scale counts of bass in test reservoirs before and after the Florida bass introductions were routinely made to help determine the overall impact of Florida bass on the total bass population. Florida bass have a larger number of lateral line scales (usually averaging 70–72) than their northern counterparts (mean reported values: 63–64.4) and this taxonomic feature, among others, has been used to help differentiate the two subspecies (Bailey and Hubbs 1949, Inman 1974). Hybridization among mixed populations regularly occurs and intermediate mean lateral line scale counts are characteristic of such populations (Bailey and Hubbs 1949, Buchanan 1968, Addison and Spencer 1971, Inman 1974).

Procedures for counting scales follow Hubbs and Lagler (1957). A probe was used to lift and count each lateral line scale anterior to the caudal crease. Specimens less than 180 mm (7 inches) were examined with a binocular scope providing a magnification of 30X. Bass used for scale count analyses were obtained by seining, electrofishing, and creel census. Scale counts were pooled annually and compared with counts made by other workers prior to the Florida bass introductions.

### Age and Growth

Initial comparisons of the age and growth of northern and Florida bass at El Capitan Reservoir involved the performance of the original stock of Florida bass (2,500 fingerlings in 1961) as contrasted with naturally produced northern bass of the same year class. Growth was determined for each subspecies by scale analysis of angler-caught fish over the period 1965 through 1973. The techniques employed were subjective to the extent that they relied on our ability to accurately distinguish pure northern and Florida bass in the creel. Lateral line scale counts and coloration formed the basis for such distinctions (Bailey and Hubbs 1949).

Subsequent growth comparisons at El Capitan Reservoir were also initiated in 1969 and 1970 which involved the marking (fin clipping) and stocking of pure northern and Florida bass from other sources. Growth of stocked bass and their subsequent contribution to the El Capitan Reservoir fishery were followed with extensive creel checks. The creel census also provided an opportunity to collect scale samples for the determination of the age and growth characteristics of a hybridized bass population which developed at El Capitan Reservoir following the liberation of Florida bass in 1961. Length and weight measurements of angler-caught bass were routinely taken as part of the creel census program and these subsequently provided a basis for the generation of length-weight expressions for each parent subspecies.

Ages of bass (other than marked groups) were determined by counting annuli on scales taken at a point near the tip of the left pectoral fin. Criteria for annuli recognition follow Rounsefell and Everhart (1953) and Lagler (1956). All scales were mounted on cellulose acetate strips and examined with a microprojector providing a magnification of 12X. Nomograph strips were used to back-calculate incremental growth.

## Vulnerability to Angling

Comparisons of the vulnerability of Florida and northern bass to angling at El Capitan Reservoir were generated from the liberation of fin clipped lots of catchable-sized bass ($\geq$ 275 mm, 10.8 inches FL)of both parent subspecies in 1969 and 1970. The study in 1970 also featured the additional marking of a group of bass obtained with electrofishing gear from the hybridized population which developed in El Capitan Reservoir after Florida bass were initially stocked in 1961. Total returns of the various marked groups were determined by creel census from 1969 through 1976. The resultant data were also used to calculate exploitation and survival estimates utilizing concepts set forth by Ricker (1958).

An additional experiment on the catchability of Florida-like bass was initiated at Sutherland Reservoir in 1973. The bass population in this impoundment, although hybridized, had rapidly assumed Florida-like characteristics following the original Florida bass introduction in 1960. Groups of catchable-sized bass were collected with electrofishing gear in both 1973 and 1974, differentially fin clipped, and returned to the reservoir. The subsequent contribution of these groups to the creel was determined from extensive creel checks conducted in 1973 and 1974. Resultant data provided a basis for estimating harvest rates which were later compared with similar parameters obtained prior to the Florida bass introduction (La Faunce, et al. 1964).

A similar experiment was initiated in 1975 at Lower Otay Reservoir which also contained a bass population with Florida-like characteristics. Catchable-sized bass were obtained with electrofishing gear in 1975 and 1976, differentially marked, and returned to the reservoir. Harvest rate estimates of marked bass were obtained by means of intensive creel checks in 1975 and 1976.

## Fishery Trends

Trends in angling quality at Sutherland and El Capitan reservoirs following the liberation of Florida bass were determined from extensive creel censuses. Access to these impoundments is controlled with a permit system and anglers were interviewed at check stations at the end of their fishing day. Over 90% of all

anglers at each reservoir were checked on days when censuses were conducted. Both reservoirs were open to angling seasonally, usually from March through early October. During the open season, fishing is normally permitted only on weekends, holidays, and one or two weekdays per week. Census levels were high; over 80% of all days that El Capitan Reservoir was open to angling were checked over the period 1967 through 1975, and a 100% sampling level was achieved at Sutherland Reservoir from 1971 through 1975. Data derived from these censuses were then compared to similar materials obtained by other workers (La Faunce, et al. 1964, Fast 1966, Lee Miller, California Department of Fish and Game, unpublished data) as a means of establishing long term fishery trends at each reservoir.

Data obtained from each angler interviewed included hours fished and an enumeration of fish caught by species and number. Systematic weight samples of each species (individuals over 1 lb) were weighed to the nearest 0.01 kg (0.02 lb). Smaller fish were weighed to the nearest gram. Data were expanded proportionally to include anglers and/ or days missed. This procedure provided a basis for the calculation of annual estimates of total use and catch. The creel census was also used to: (i) help define lateral line scale count changes; (ii) determine harvest rates of experimental lots of marked bass; and (iii) obtain scales for age and growth analysis. To that extent, the census may be considered as an integral feature of the entire program.

## RESULTS

### Lateral Line Scale Count Changes

Lateral line scale counts from the northern bass population at Lower Otay Reservoir were obtained in 1957. Counts ranged from 58 to 67, with a mean of 62.5. Florida bass introductions were made in 1960 and 1961 (2,089 yearlings in 1960 and 5,500 fingerlings in 1961) and scale counts from samples of stocked fish averaged 70.4. Following these introductions, mean scale counts of the Lower Otay bass population rapidly increased. Fingerling bass sampled in 1963 had a mean lateral line scale count of 69.2. Subsequent samples continued to produce high counts and all samples taken after 1968 had mean values of 70 or more (Table 2).

A sample of northern bass from Sutherland Reservoir in 1960 had a mean lateral line scale count of 63.7. Florida bass were introduced in 1960 (800 yearlings with a mean lateral line count of 70.3) and mean counts of the Sutherland Reservoir bass population rapidly increased thereafter. In 1961, sample of fingerlings produced a mean count of 67.5 (Table 2). A continuing upward trend was noted throughout the study period and a maximum mean lateral line scale count of 70.2 was recorded in 1975.

**TABLE 2. Changes in Lateral Line Scale Counts of Largemouth Bass Populations at Lower Otay, Sutherland, El Capitan, and San Vicente Reservoirs.**

| Collection Year | *Lower Otay*[a] | | | *Sutherland*[c] | | | *El Capitan*[e] | | | *San Vicente*[g] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *Bass*[b] *sampled* | *Scale counts* *Range* | *Scale counts* *Mean* | *Bass*[d] *sampled* | *Scale counts* *Range* | *Scale counts* *Mean* | *Bass*[f] *sampled* | *Scale counts* *Range* | *Scale counts* *Mean* | *Bass*[h] *sampled* | *Scale counts* *Range* | *Scale counts* *Mean* |
| 1957 | 46 | 58-67 | 62.5 | – | – | – | – | – | – | – | – | – |
| 1960 | – | – | – | 31 | 60-68 | 63.7 | – | – | – | – | – | – |
| 1961 | – | – | – | 125 | 61-76 | 67.5 | 240[i] | 58-69 | 63.6 | – | – | – |
| 1962 | – | – | – | – | – | – | 65 | 58-68 | 63.4 | – | – | – |
| 1963 | 130 | 63-67 | 69.2 | – | – | – | 318 | 58-72 | 64.0 | – | – | – |
| 1964 | 32 | 64-72 | 68.3 | – | – | – | 143 | 58-72 | 64.7 | – | – | – |
| 1965 | – | – | – | 80 | 60-75 | 67.4 | 192 | 58-72 | 65.4 | – | – | – |
| 1966 | 106 | 62-76 | 69.6 | 120 | 60-76 | 68.0 | 155 | 58-73 | 65.3 | 200 | 58-69 | 63.5 |
| 1967 | – | – | – | 101 | 61-76 | 68.8 | 286 | 58-74 | 65.6 | 138 | 58-68 | 63.7 |
| 1968 | 100 | 63-75 | 69.2 | – | – | – | 220 | 58-74 | 65.7 | 42 | 57-68 | 63.7 |
| 1969 | 103 | 65-76 | 70.1 | – | – | – | 159 | 59-78 | 65.6 | 69 | 60-68 | 63.8 |
| 1970 | – | – | – | – | – | – | 203 | 58-73 | 65.7 | 92 | 57-71 | 63.9 |
| 1971 | – | – | – | 127 | 64-76 | 69.5 | 187 | 58-76 | 66.1 | 258 | 57-74 | 65.7 |
| 1972 | – | – | – | 73 | 62-76 | 69.7 | 313 | 58-74 | 66.2 | 459 | 59-74 | 65.7 |
| 1973 | 100 | 66-77 | 71.4 | 455 | 60-78 | 69.8 | 468 | 59-76 | 66.7 | 710 | 57-75 | 65.6 |
| 1974 | – | – | – | 441 | 63-77 | 70.1 | 756 | 59-77 | 66.7 | 832 | 58-75 | 66.4 |
| 1975 | 233 | 64-77 | 70.8 | 510 | 63-78 | 70.2 | 601 | 58-76 | 66.9 | 358 | 58-77 | 66.7 |
| 1976 | 833 | 63-78 | 70.6 | 352 | 63-81 | 70.3 | 1180 | 57-76 | 66.8 | 1837 | 58-79 | 68.8 |

[a] Florida bass initially stocked in 1960.
[b] Angler-caught bass sampled in 1957, 1966, 1975, and 1976. Remaining samples were fingerlings taken by seining and electrofishing.
[c] Florida bass initially stocked in 1960.
[d] Angler-caught bass sampled in 1960, 1965, 1966, and 1972 through 1976. Remaining samples were fingerlings taken by seining and electrofishing.
[e] Florida bass initially stocked in 1961.
[f] All bass sampled were caught by anglers.
[g] Florida bass initially stocked in 1969.
[h] Fingerling bass taken by seining and electrofishing comprise 1968 sample. Remaining samples angler-caught.
[i] Pooled sample taken over the period 1958–1961.

Extensive sampling of northern bass populations at El Capitan Reservoir over the period 1958–1961 produced mean lateral line scale counts of 63.6 (Table 2). Following the introduction of Florida bass in 1961 (2,500 fingerlings with a mean count of 70.7), mean scale counts increased, although at a lesser rate than occurred at Lower Otay and Sutherland reservoirs. Annual mean counts over the period 1965 through 1970 ranged from 65.3 in 1966 to 65.7 in 1968 and 1970. Further increases were subsequently noted and a maximum mean count of 66.9 was recorded in 1975.

Northern bass populations at San Vicente Reservoir produced annual mean lateral line scale counts (1966 through 1969) ranging from 63.5 to 63.8. Florida bass (495 adults with a mean count of 70.1) were stocked in 1969. By 1971, the mean scale count of angler-caught bass reached 65.7 and a maximum value of 68.8 was recorded in 1976 (Table 2).

The impact of Florida bass introductions on the texture of bass populations, as determined from lateral line scale counts, varied considerably among study waters. Mean counts at Sutherland and Lower Otay reservoirs rapidly increased and now are within ranges normally reported for pure Florida bass populations. Individuals with low laterial line scale counts persist in these populations, however, which indicates that some northern and/or hybrid bass are present. A similar, although less complete, transition has also occurred at San Vicente Reservoir. In contrast, the changes which occurred at El Capitan Reservoir, while significant, were far less rapid.

We wish to emphasize that the increases in lateral line scale counts at each test water was largely the result of hybridization and not due merely to the successful establishment of Florida bass populations. Frequency distributions of lateral line scale counts were critically examined for biomodality; a phenomenon which would occur if discrete populations of northern and Florida bass were present. No evidence of biomodality was found and it is evident that hybridization was a key factor relative to the changes which occurred.

## Age and Growth

### *1961 Experiment*

A growth comparison was made of 2,500 fingerling Florida bass stocked in El Capitan Reservoir in 1961 with both naturally-produced and stocked northern bass of the same year class. Scale samples from 123 northern bass and 120 Florida bass of the 1961 year class were collected during a creel census program at El Capitan Reservoir from 1965 through 1972. Additional scale samples from these cohorts were taken earlier by other workers, providing a total of 168 northern bass and 134 Florida bass for age and growth analysis.

Growth of northern bass slightly exceeded Florida bass at age I. In all subsequent years, however, estimated mean lengths and weights of Florida bass were greater at any given age than northern bass. Absolute differences in recorded growth histories were positively correlated with age. Northern bass reached estimated weights of 500 g (1.10 lb), 1,724 g (3.80 lb) and 2,510 g (5.53 lb) at ages II, V, and VIII, respectively. Comparative values for Florida bass were 681 g (1.50 lb), 2,923 g (6.44 lb), and 4,557 g (10.04 lb) (Table 3).

**TABLE 3. Age and Growth of the 1961 Year Class of Northern and Florida Largemouth Bass at El Capitan Reservoir.**

| | *Northern bass* | | | *Florida bass* | | |
|---|---|---|---|---|---|---|
| *Age* | *Number * sampled* | *Mean † length (mm)* | *Mean ‡ weight (g)* | *Number * sampled* | *Mean † length (mm)* | *Mean ‡ weight (g)* |
| I | 168 (12) | 154.1 | 92 | 134 (4) | 150.3 | 67 |
| II | 156 (26) | 295.2 | 500 | 130 (8) | 323.9 | 681 |
| III | 130 (7) | 374.2 | 973 | 122 (2) | 398.5 | 1,290 |
| IV | 123 (47) | 415.7 | 1,318 | 120 (29) | 448.2 | 1,883 |
| V | 76 (28) | 455.6 | 1,724 | 91 (29) | 517.9 | 2,923 |
| VI | 48 (18) | 485.5 | 2,072 | 79 (20) | 560.0 | 3,776 |
| VII | 30 (23) | 515.0 | 2,445 | 59 (27) | 586.2 | 4,359 |
| VIII | 7 (7) | 517.0 | 2,510 | 32 (14) | 593.3 | 4,557 |
| IX | – | – | – | 18 (4) | 629.9 | 5,510 |
| X | – | – | – | 14 (8) | 651.1 | 6,041 |
| XI | – | – | – | 6 (6) | 646.3 | 5,919 |

* Number in parentheses indicates number of bass sampled at given age; i.e., 12 age I northern bass collected.
† Estimates based on back-calculation of composite sample.
‡ Estimated values based on length-weight expressions developed separately for each subspecies.

### *1968 Experiment*

A second growth assessment of northern and Florida bass was initiated at El Capitan Reservoir in 1968. In July and August of that year, two groups of 5,015 differentially-marked fingerling bass, one group northern and one group Florida, were stocked. Each group was obtained from local sources containing pure populations of each subspecies. Stocked Florida bass had a mean length of 73 mm (2.9 inches) FL and were marked by removal of the right pectoral fin. Northern bass had a mean length of 75 mm (3.0 inches) FL and received a left pectoral fin clip. Returns to the creel and an analysis of growth of the two groups was based on creel census conducted from 1969 through 1973.

Growth of these cohorts was considerably less than that observed in the 1961 experiment although differential growth patterns were similar. At age I, northern and Florida bass had respective mean weights of 41 g (0.09 lb) and 36 g (0.08 lb). In subsequent years, estimated lengths and weights of Florida bass exceeded that of northern bass at any given age. Estimated mean weights of Florida bass at ages II and V, for example, were 376 g (0.83 lb) and 1,090 g (2.40 lb), respectively. By contrast, northern bass of the same ages had mean estimated weights of 369 g (0.81 lb) and 890 g (1.96 lb) (Table 4).

**TABLE 4. Age and Growth of Northern and Florida Bass Stocked as Fingerlings in El Capitan Reservoir in 1968**

| | *Northern bass* | | | *Florida bass* | | |
|---|---|---|---|---|---|---|
| | *Number * sampled* | *Mean † length (mm)* | *Mean ‡ weight (g)* | *Number * sampled* | *Mean † length (mm)* | *Mean ‡ weight (g)* |
| I | 73 (10) | 132.1 | 41 | 141 (12) | 124.2 | 36 |
| II | 63 (26) | 289.5 | 369 | 129 (39) | 295.0 | 376 |
| III | 37 (20) | 338.1 | 592 | 90 (45) | 354.6 | 631 |
| IV | 17 (12) | 354.4 | 715 | 45 (25) | 382.0 | 936 |
| V | 5 (5) | 381.4 | 890 | 20 (20) | 411.8 | 1,090 |

* Number in parentheses indicates number of bass sampled at given age; i.e., 10 age I northern bass collected.
† Estimates based on back-calculation of composite sample.
‡ Estimated values based on length-weight expressions developed separately for each subspecies.

*1970 Experiment*

Additional marked groups of each subspecies were stocked in El Capitan Reservoir as yearlings in June 1970. A total of 2,886 northern bass and 2,349 Florida bass was differentially marked by removal of the right and left pectoral fins, respectively. Both groups were comparable in size when stocked; northern bass had a mean length of 204.8 mm (8.1 inches) FL while Florida bass averaged 200.7 mm (7.9 inches) FL. Growth analyses of these groups were based on fish observed in the creel over the period 1971 through 1973.

Estimated growth of Florida bass exceeded that of northern bass in all study years, although growth of both later cohorts was less than that recorded earlier. At age II, Florida bass had a mean length of 275.0 mm (10.8 inches) FL as compared to 256.9 mm (10.1 inches) FL for northern bass. By age IV, Florida and northern bass had estimated mean lengths of 371.4 mm (14.6 inches) FL and 356.9 mm (14.1 inches) FL, respectively (Table 5).

**TABLE 5. Age and Growth of Northern and Florida Bass Stocked as Yearlings in El Capitan Reservoir in 1970.**

| | *Northern bass* | | | *Florida bass* | | |
|---|---|---|---|---|---|---|
| *Age* | *Number * sampled* | *Mean † length (mm)* | *Mean ‡ weight (g)* | *Number * sampled* | *Mean † length (mm)* | *Mean ‡ weight (g)* |
| II | 312 (95) | 256.9 | 241 | 161 (44) | 275.0 | 315 |
| III | 177 (137) | 313.2 | 515 | 91 (65) | 332.3 | 592 |
| IV | 40 (40) | 356.9 | 665 | 26 (26) | 371.4 | 837 |

* Number in parentheses indicates number of bass sampled at given age; i.e., 95 age II northern bass collected.
† Estimates based on back-calculation of composite sample.
‡ Estimated values based on length-weight expressions developed separately for each subspecies.

*Hybrid Bass*

Growth characteristics of a hybridized bass population which developed at El Capitan Reservoir following the introduction of Florida bass were determined from scale samples of angler-caught fish taken from 1966 through 1971. The scale collection provided a basis for estimating growth of naturally produced year classes from 1963 through 1965. While it is clear that the bass population, as a whole, became hybridized over the time period involved, we cannot rule out the possibility that portions of our sample were obtained from genetically pure specimens of the two parent subspecies.

All year classes exhibited growth patterns that were intermediate to the calculated growth of Florida and northern bass of the 1961 year class. Bass from the hybridized population achieved a mean length in excess of 500 mm (19.7 inches) FL at age VI (Table 6). In contrast, Florida and northern bass reached comparable lengths at ages V and VII, respectively (Table 3). While these growth comparisons are not direct because different age groups were involved, the evidence suggests that hybrid bass grow at intermediate rates to the parent subspecies.

**TABLE 6. Age and Growth of 1963, 1964, and 1965 Year Classes of Hybridized Bass Population at El Capitan Reservoir*.**

| | *Year class* | | | | | |
|---|---|---|---|---|---|---|
| | *1963* | | *1964* | | *1965* | |
| *Age* | *Number† sampled* | *Total length‡ (mm)* | *Number† sampled* | *Total length‡ (mm)* | *Number† sampled* | *Total length‡ (mm)* |
| I | 184 (0) | 92.3 | 165 (0) | 86.5 | 139 (0) | 113.1 |
| II | 184 (0) | 268.6 | 165 (0) | 283.5 | 139 (0) | 291.4 |
| III | 184 (3) | 387.4 | 165 (11) | 395.0 | 139 (0) | 388.7 |
| IV | 181 (23) | 449.7 | 154 (17) | 450.9 | 139 (11) | 422.6 |
| V | 158 (25) | 499.5 | 137 (19) | 476.6 | 128 (33) | 477.5 |
| VI | 133 (34) | 517.3 | 118 (38) | 524.6 | 75 (75) | 516.3 |
| VII | 99 (34) | 559.1 | 80 (80) | 554.8 | – | – |
| VIII | 65 (65) | 585.2 | – | – | – | – |

* Data reflect growth of population judged to be hybridized from lateral line scale counts. Portions of sample may have been taken from genetically pure individuals of either parent subspecies.

† Number in parentheses indicates number of bass sampled at given age; i.e., 23 age IV bass collected from the 1963 year class

‡ Estimates based on back-calculation of composite sample

### *Length-Weight Relationships*

Length-weight expressions for both northern and Florida bass were generated from the same groups of fish used to initiate comparative growth experiments at El Capitan Reservoir in 1961 and 1968. The 1961 northern bass year class had a length-weight relationship expressed by the equation $\text{Log}_{10}$ Weight = 2.8951 ($\text{Log}_{10}$ Length) − 4.4701, where weight is expressed in pounds and length in inches. By contrast, Florida bass of the same year class had a length-weight relationship of $\text{Log}_{10}$ Weight = 3.1714 ($\text{Log}_{10}$ Length) − 5.1476. Comparable expressions for the 1968 year class of northern and Florida bass were $\text{Log}_{10}$ Weight = 3.0569 ($\text{Log}_{10}$ Length) − 4.9451 and $\text{Log}_{10}$ Weight = 3.2604 ($\text{Log}_{10}$ Length) − 5.4236, respectively. Based on these relationships, Florida bass are heavier than the northern subspecies at lengths of 300 mm (11.8 inches) FL or more (Table 7).

**TABLE 7. Length-Weight Relationships of Northern and Florida Bass at El Capitan Reservoir (1961 Year Class).**

| | *Weight (g)* | |
|---|---|---|
| *Fork length (mm)* | *Northern * bass* | *Florida † bass* |
| 100 | 13 | 11 |
| 200 | 121 | 112 |
| 300 | 439 | 441 |
| 400 | 1,095 | 1,171 |
| 500 | 2,224 | 2,491 |
| 600 | 3,968 | 4,621 |
| 700 | 7,000 | 7,783 |

* Length-weight values based on expression $\text{Log}_{10}$ Weight = 2.8951 ($\text{Log}_{10}$ Length) − 4.4701 where weight is expressed in pounds and length in inches (FL).

† Length weight values based on expression $\text{Log}_{10}$ Weight = 3.1714 ($\text{Log}_{10}$ Length) − 5.1476 where weight is expressed in pounds and length in inches (FL).

## Vulnerability to Angling

*El Capitan Reservoir—1969 Experiment*

A preliminary test to compare the catchability (or vulnerability to angling) of northern and Florida bass was undertaken at El Capitan Reservoir in 1969. Totals of 714 northern bass and 708 Florida bass were obtained from nearby waters with electrofishing gear, differentially fin clipped, and liberated into El Capitan Reservoir prior to the opening of the fishing season in March 1969. All test fish were considered to be of catchable size ($\geq$275 mm, 10.8 inches FL). The northern bass had a mean length of 302.7 mm (11.9 inches) FL and were marked by removal of the left pelvic fin. Florida bass had their right pelvic fin excised and averaged 304.8 mm (12.0 inches) FL. Angler recovery patterns for both groups were determined from extensive creel checks conducted from 1969 through 1976.

Recoveries at the completion of the 1976 fishing season (8 years) totaled 74.5% for northern bass and 60.6% for Florida bass. Northern bass were harvested at relatively high rates and first year (1969) returns exceeded recoveries in all subsequent years combined. Florida bass were far less vulnerable to angling and recoveries between years were more evenly distributed throughout the study period. Based on concepts set forth by Ricker (1958), the annual exploitation (angler harvest) rate of northern bass was 0.41 as compared to only 0.17 for Florida bass (Table 8).

**TABLE 8. Angler Recovery of Fin Clipped Northern and Florida Bass Released in El Capitan Reservoir in the Winter of 1968–69.**

| *Bass subspecies* | *Number stocked* | *Recoveries** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | *1969* | *1970* | *1971* | *1972* | *1973* | *1974* | *1975* | *1976* | *Totals* |
| Northern.... | 714 | 291 | 123 | 70 | 31 | 9 | 6 | 2 | 0 | 532 † |
| | | (40.8) | (17.2) | (9.8) | (4.3) | (1.3) | (0.8) | (0.3) | (0.0) | (74.5) |
| Florida........ | 708 | 109 | 91 | 98 | 64 | 32 | 17 | 14 | 4 | 429 ‡ |
| | | (15.4) | (12.9) | (13.8) | (9.0) | (4.5) | (2.4) | (2.0) | (0.6) | (60.6) |

* Numbers in parentheses represent the percent age return from the initial plant.

† From Ricker (1958), we calculate: annual survivial rate (s) = 0.45; annual mortality rate (a) = 0.55; annual expectation of death due to fishing (u) = 0.41 and annual expectation of death due to natural causes (v) = 0.14.

‡ (s) = 0.75, (a) = 0.25, (u) = 0.17, and (v) = 0.08.

*El Capitan Reservoir—1970 Experiment*

To reinforce conclusions drawn from the 1969 experiment, a second series of differentially marked groups of catchable-sized bass were stocked in El Capitan Reservoir prior to the opening of the fishing season in 1970. These groups included: 1,063 northern bass (mean length 331.2 mm, 13.0 inches FL) obtained from nearby waters with electrofishing gear and marked by removal of the left ventral and pectoral fins; 600 intergrade bass (mean length 353.6 mm, 13.9 inches FL) collected directly from El Capitan Reservoir by angling or with electrofishing gear and marked by excision of both ventral fins; and 953 Florida bass (mean length 333.9 mm, 13.1 inches FL) collected from other sources with electrofishing gear and marked by removal of the right ventral and pectoral fins. Recoveries of these groups were determined from the creel census previously described.

At the completion of the angling season in 1976 (7 years), recoveries for

northern, hybrid, and Florida bass totaled 73.0, 76.3, and 57.5%, respectively. The northern bass harvest pattern featured high exploitation, with first year recoveries (51.0%) exceeding recoveries in all subsequent years combined. Florida bass were far less vulnerable to angling and only 20.0% of the Florida bass plant was seen in 1970. Hybrid bass were caught at intermediate annual rates to the parent subspecies, although total returns from this group were the highest recorded (Table 9).

**TABLE 9. Angler Recovery of Fin Clipped Northern, Hybrid, and Florida Bass Released in El Capitan Reservoir in the Winter of 1969–70.**

| *Bass subspecies* | *Number stocked* | *Recoveries* [1] | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | *1970* | *1971* | *1972* | *1973* | *1974* | *1975* | *1976* | *Totals* |
| Northern .... | 1,063 | 542 | 149 | 69 | 11 | 3 | 2 | 0 | 776 [3] |
| | | (51.0) | (14.0) | (6.5) | (1.0) | (Tr) [2] | (Tr) [2] | (Tr) [2] | (73.0) |
| Hybrid ........ | 600 | 213 | 111 | 68 | 36 | 14 | 11 | 5 | 458 [4] |
| | | (35.5) | (18.5) | (11.3) | (6.0) | (2.3) | (1.8) | (Tr) [2] | (76.3) |
| Florida ........ | 953 | 191 | 98 | 86 | 40 | 49 | 65 | 18 | 547 [5] |
| | | (20.0) | (10.3) | (9.0) | (4.2) | (5.1) | (6.8) | (1.9) | (57.4) |

[1] Numbers in parentheses represent the percentage return from the initial plant.
[2] Less than 1.0%.
[3] From Ricker (1958), we calculate: annual survival rate (s) = 0.30; annual mortality rate (a) = 0.70; annual expectation of death due to fishing (u) = 0.51; and annual expectation of death due to natural causes (v) = 0.19.
[4] (s) = 0.54, (a) = 0.46, (u) = 0.36, and (v) = 0.10.
[5] (s) = 0.67, (a) = 0.33, (u) = 0.20, and (v) = 0.13.

We wish to emphasize that the hybrids used in this experiment were residents of El Capitan Reservoir and were subjected to less handling than the parent subspecies. Such differences in handling procedure may have induced differential mortalities among groups of marked bass with subsequent effects on their return to the creel.

### *Sutherland Reservoir Experiment*

Harvest (exploitation) rates of a hybridized bass population at Sutherland Reservoir which had assumed predominately Florida-like characteristics were also determined to assess the overall effects of Florida bass introductions on the catchability of bass populations. During the winters (closed season) of 1972–73 and 1973–74, 472 and 408 bass, respectively, were collected from Sutherland Reservoir with electrofishing gear, differentially fin clipped, and released. Only bass regarded as "catchable" were retained for marking. Returns of these lots were determined from creel checks from 1973 through 1976.

A total of 263 bass (55.7%) from the 1973 plant was captured by the end of the 1976 fishing season. Mean annual exploitation and natural mortality rates of this group were 0.25 and 0.13, respectively (Ricker 1958). Returns from the 1974 plant totaled 157 bass (37.7%) through 1976 which produced mean annual exploitation and survival rates, respectively, of 0.19 and 0.20. We note that the mean annual bass exploitation rate at Sutherland Reservoir prior to the Florida bass introduction (1956 through 1960) was 0.38 (La Faunce, et al. 1964). This comparison helped confirm the findings obtained earlier at El Capitan Reservoir; Florida bass (and Florida-like hybrids) are less vulnerable to angling than their northern counterparts.

*Lower Otay Reservoir Experiment*

Estimates of bass exploitation rates at Lower Otay Reservoir were obtained in 1975 and 1976 utilizing procedures similar to those used at Sutherland Reservoir in 1973 and 1974. Groups of catchable-sized bass were captured with electrofishing gear during the winters (closed season) of 1974–75 and 1975–76 (522 and 451 bass, respectively), differentially fin clipped, and returned to the reservoir. Harvest estimates were determined from creel checks in 1975 and 1976.

Estimated returns from the 1975 plant totaled 319 bass by the end of the 1976 fishing season. Based on Ricker (1958), mean annual exploitation and natural mortality rates were calculated to be 0.43 and 0.14, respectively. An estimated 133 marked bass from the 1976 plant were captured in that year, which produced an exploitation rate of 0.29. These harvest estimates are the highest recorded in San Diego County impoundments containing bass populations with Florida-like characteristics. Angling pressure on the black bass segment of the Lower Otay Reservoir fishery is more intense than that recorded at other test waters and this result does not alter our basic conclusion with regard to the relative vulnerability to angling of the two subspecies.

## Fishery Trends

*El Capitan Reservoir*

The introduction of Florida bass in El Capitan Reservoir was followed by a highly significant increase in largemouth bass production. Over the period 1960 through 1962, the mean annual bass harvest (yield) was 1,776 kg (3,797 lb). During this time interval, fish caught had lateral line counts similar to pure northern bass (Table 2) and it is clear that the introduction of Florida bass in 1961 had not yet had a significant impact on the catchable-sized segment of the bass population. By 1965, the bass population was hybridized (Table 2) and annual bass harvests increased to a mean value of 4,022 kg (8,848 lb) over the period 1965-67. Further increases were noted in later years and the current yield is nearly four times greater than it was prior to the Florida bass introduction (Table 10).

**TABLE 10. Trends in Angling Quality for Largemouth Bass, Bluegill, and Catfish at El Capitan Reservoir, 1960–1975.**

| | *Mean annual catch and use statistics** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | *Largemouth bass* | | *Bluegill* | | *Catfish* † | | *Totals* ‡ | |
| *Time interval (years)* | *Number anglers* | *Number caught* | *Weight (kg)* | *Number caught* | *Weight (kg)* | *Number caught* | *Weight (kg)* | *Number caught* | *Weight (kg)* |
| 1960–1962 | 10,173 | 2,106 | 1,776 | 40,969 | 3,440 | 11,547 | 3,044 | 54,622 | 8,260 |
| 1965–1967 | 13,586 | 5,007 | 4,022 | 57,169 | 5,313 | 3,544 | 2,694 | 65,720 | 12,029 |
| 1968–1970 | 17,328 | 6,879 | 6,277 | 61,324 | 6,912 | 5,168 | 4,398 | 73,371 | 17,587 |
| 1971–1973 | 18,053 | 6,100 | 6,084 | 8,334 | 948 | 5,763 | 4,480 | 20,197 | 11,512 |
| 1974–1975 | 19,736 | 7,407 | 6,578 | 9,024 | 832 | 4,557 | 2,113 | 20,988 | 9,523 |

* All statistics presented as mean annual values over the time interval given; e.g., an average of 10,173 anglers per year fished El Capitan over the period 1960–62.

† Brown bullhead, *Ictalurus nebulosus*, black bullhead, *I. melas*, and yellow bullhead, *I. natalis*, dominated the catfish catch prior to 1962. Stocked channel catfish, *I. punctatus*, dominated after 1965.

‡ Total reflects only largemouth bass, bluegill, and catfish. Crappie, *Pomoxis spp*, and incidental species taken are listed in Appendix 1.

Bluegill catches showed an upward trend through 1970 followed by an abrupt decline (Table 10, Appendix 1). While the precise nature of the interaction between bluegill and bass at El Capitan Reservoir has not been adequately defined, it appears possible that increases in bass biomass are partially responsible for the apparent decline in the bluegill fishery. Summer water level fluctuations at El Capitan Reservoir tended to increase after 1966 and this factor may have had a detrimental impact on bluegill reproduction with subsequent adverse effects on the bluegill fishery. The harvest of catfishes showed a slight upward trend over the course of this investigation although this is attributed largely to a channel catfish stocking program and the subsequent development of a self-sustaining population. Bullheads, which dominated the catfish catch prior to 1962, now comprise a very minor segment of the fishery.

We conclude that the introduction of Florida bass and the subsequent development of a hybridized bass population, with behavioral characteristics intermediate to the northern and Florida forms, has had a desirable impact on the black bass segment of the El Capitan Reservoir fishery. It is unclear whether or not the recent decline in the bluegill catch is related to the Florida bass introduction. The issue is further clouded by the observation that El Capitan Reservoir contained abnormally large quantities of water in 1969 and 1970 (Appendix 1). This factor could have materially enhanced centrarchid reproduction and survival in those years with subsequent fisheries benefits unrelated to the Florida bass introduction.

*Sutherland Reservoir*

In contrast to results obtained at El Capitan Reservoir, improvements in the quality of bass angling at Sutherland Reservoir following the introduction of Florida bass in 1960 could not be demonstrated. Census data collected from 1956 through 1960 were obtained when the reservoir was new under conditions of an expanding fishery (La Faunce, et al. 1964) and such materials cannot be used as a baseline from which to evaluate the impact of Florida bass introductions. While bass yields were generally higher when the fishery was dominated by the northern subspecies (Table 11, Appendix 2), this result may be due to the high fish production often associated with new reservoirs. Moreover, relatively high water levels in 1958 and 1959 (presumably coupled with increased spawning success) may have contributed to the high yields recorded in 1960 (Appendix 2). While these observations clearly reduce the comparability of the data (pre- and post-Florida bass), it does not appear that the introduction of Florida bass has benefited bass angling at Sutherland Reservoir over the long term.

**TABLE 11. Trends in Angling Quality for Largemouth Bass, Bluegill, Green Sunfish, and Catfish at Sutherland Reservoir, 1956–1975.**

| | Mean annual catch and use statistics [1] | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Largemouth bass | | Bluegill and/or [2] green sunfish | | Catfish [3] | | Totals | |
| *Time interval (years)* | *Number anglers* | *Number caught* | *Weight (kg)* | *Number caught* | *Weight (kg)* | *Number caught* | *Weight (kg)* | *Number caught* | *Weight (kg)* |
| 1956–1957 [4] | 7,008 | 2,647 | 1,325 | 4,957 | 405 | 34 | 16 | 7,638 | 1,746 |
| 1958–1960 [4] | 14,921 | 8,649 | 4,973 | 57,734 | 4,718 | 509 | 231 | 66,892 | 9,922 |
| 1965–1966 [5] | 13,578 | 4,767 | 3,312 | 101,385 | 11,062 | 397 | 137 | 106,549 | 14,511 |
| 1971–1972 | 11,421 | 3,070 | 2,940 | 18,919 | 2,039 | 1,893 | 3,355 | 23,882 | 8,334 |
| 1973–1975 | 12,183 | 1,636 | 1,601 | 27,706 | 3,183 | 3,219 | 5,188 | 32,561 | 9,972 |

[1] All statistics presented as mean annual values over time interval given; i.e., an average of 2,646 largemouth bass per year caught over the period 1956–57.
[2] Green sunfish, *Lepomis cyanellus*, dominated in 1956–57. Bluegill dominated thereafter.
[3] Brown bullhead dominated over period 1956–65. Channel catfish dominated from 1971–74.
[4] La Faunce, Kimsey, and Chadwick (1964).
[5] Lee Miller, unpublished data.

The lack of comparability of the data precludes accurate interpretation of the impact, if any, of Florida bass on bluegill populations. High bluegill yields recorded over the period 1958 through 1960 (Table 11) may be a reflection of high water levels in 1958 and 1959 (Appendix 2). The very high bluegill harvests of 1965 and 1966 occurred at a time when the bass population (with regard to lateral line scale counts) was intermediate to the parent subspecies (Table 2). These data, however, are based on limited census effort (Appendix 2) and are subject to a degree of sample error. Bluegill yields from 1971 through 1975, after the bass population had assumed Florida-like characteristics, were comparatively low (Table 11, Appendix 2). Summer water level fluctuations at Sutherland Reservoir also increased after 1966, however, and this factor may have contributed to the depressed bluegill catch in recent years. Increases in catfish production are the result of a channel catfish stocking program and are unrelated to the Florida bass introduction.

## DISCUSSION

Florida bass have demonstrated a clear ability to reduce or eliminate the genetic integrity of northern bass stocks in San Diego County impoundments. Based on coloration and lateral line scale counts, bass populations in Lower Otay and Sutherland reservoirs are now difficult or impossible to distinguish from the pure Florida strain. A rapid increase in lateral line scale counts is occurring at San Vicente Reservoir and we anticipate that this population will also assume Florida-like characteristics within a few years. El Capitan Reservoir is a notable exception; bass populations have remained in a relatively stable, intermediate state for a number of years.

A variety of mechanisms may be responsible for the apparent selection of the Florida bass genotype in mixed populations. Florida bass spawn earlier than northern bass (Hunsacker and Crawford 1964, Bottroff 1967, Chew 1974, 1975), which may convey a competitive advantage to Florida bass fry. Evidence is now available which indicates that large (early spawned) members of a given bass year class suffer far less mortality than their later-hatched counterparts (Aggus and Elliot 1975, von Geldern and Mitchell 1975) and this factor alone may

account for the success of Florida bass introductions. Our findings on the low catchability and inherent high survival of Florida bass, (as opposed to the northern form) have been recorded elsewhere (Zolczynski and Davies 1976) and such differential exploitation would clearly tend to favor Florida bass dominance.

We note that northern bass populations present in test waters at the time Florida bass were introduced are largely descendants of original stocks imported from Illinois (Shebley 1917). Genetic variability within northern bass stocks which is related to latitude has been documented by Childers (1975) and it appears possible that the geographic origin of northern stocks is a factor which affects the relative capacity of the two forms to compete with each other. In this regard, environmental conditions in San Diego County more closely resemble Florida than Illinois and this factor may have contributed to the success of the Florida bass introductions.

Our findings on the early growth of northern and Florida bass are generally comparable to those recorded by other workers (Sasaki 1961, Clugston 1964, Miller 1965, Addison and Spencer 1971, Davies 1973, Zolczynski and Davies 1976); growth to age I is similar or northern bass grow more rapidly. The validity of this result with regard to naturally-produced year classes carries with it the assumption that mortalities (to age I) which are size-related exert equal influence on both subspecies. Florida bass initiate spawning earlier than their northern counterparts, which may convey a competitive advantage, with subsequent high survival, to Florida bass fry. Increased competition on late-spawned northern bass could act as a selective force which favors the survival of virgorous (rapidly growing) individuals and this factor may have contributed to the results attained. The more rapid growth achieved by older Florida bass in the same environment has not been previously recorded; a result possibly influenced by the genetic background of the northern stocks tested.

Desirable changes in San Diego County reservoir fisheries following Florida bass introductions center largely on: (i), increased bass production and yield from populations displaying intermediate lateral line scale counts (El Capitan Reservoir); and (ii), high incidence of trophy-sized specimens. Prior to the introduction of the Florida strain, bass over 4.1 kg (9 lb) were rarely captured. Such specimens are now commonplace; over 600 bass ranging from 4.1 to 9.5 kg (9.0 to 20.9 lb) were reported taken from San Diego County impoundments over the period 1969 through 1973. The increased incidence of large bass in the catch is reflected by a general increase in the mean size of bass taken at both Sutherland and El Capitan reservoirs (Appendix 1 and 2).

While we were unable to demonstrate increased bass production and/or yield from impoundments containing bass populations with Florida-like characteristics, it is clear that Lower Otay Reservoir provides angling of exceptional quality. Based on extensive creel checks, the estimated catch in 1975 and 1976 was 8,569 and 6,007 bass, respectively (Table 12). These estimates translate to a mean annual yield in excess of 30 kg/ha (27 lb/acre), a value comparable to that reported for intensively managed public fishing lakes in Alabama (Byrd and Crance 1965). Bass populations such as those now present in Lower Otay and Sutherland reservoirs are also resistant to overharvest by anglers; a problem of some significance in many parts of northern and central California (Rawstron and Hashagen 1972, von Geldern 1972, Rawstron and Reavis 1974).

**Table 12. Annual Catch and Use Estimates at Lower Otay Reservoir, 1975 and 1976.**

| | | *Largemouth bass* | | *Other[2] centrarchids* | | *Catfish and/or[3] bullheads* | | *Totals[4]* | |
|---|---|---|---|---|---|---|---|---|---|
| *Year[1]* | *Number anglers* | *Number caught* | *Weight (kg)* | *Number caught* | *Weight (kg)* | *Number caught* | *Weight (kg)* | *Number caught* | *Weight (kg)* |
| 1975 | 20,166 | 8,569 | 5,416 | 1,835 | 420 | 1,181 | 2,499 | 11,585 | 8,335 |
| 1976 | 15,121 | 6,007 | 3,430 | 5,096 | 836 | 966 | 1,736 | 12,069 | 6,002 |
| Totals | 35,287 | 14,576 | 8,846 | 6,931 | 1,256 | 2,147 | 4,235 | 23,654 | 14,337 |

[1] Lower Otay Reservoir open to angling on 105 days in both 1975 and 1976. Censuses conducted on all 105 days. Mean surface area in 1975 and 1976 was 122 and 146 ha, respectively.

[2] Other centrarchids include bluegill, green sunfish, and white crappie, *Pomoxis annularis*.

[3] Channel catfish, white catfish, and brown bullhead taken.

[4] Does not include incidental catches of golden shiner, *Notemigonus crysoleucas*.

Publicity on the capture of large Florida (or Florida-like) bass in San Diego County (Smith 1971) has helped stimulate their transfer to more northern latitudes. Recent studies in Missouri indicate that Florida bass suffer higher winter mortality rates than native northern bass (Johnson 1975) and such transfers could result in the introduction of maladaptive genes to the overall detriment of bass populations (Chew 1975, Childers 1975). While Florida bass have had, on the whole, a positive impact on the black bass fisheries in San Diego County, questions concerning their genetic adaptability and their impact on lesser sunfishes should be resolved before further introductions into northern waters are made.

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**APPENDIX 1. Annual Catch and Use Estimates at El Capitan Reservoir, 1960-62 and 1965-75**

| Year[1] | Days open[2] to angling | Number of anglers | Mean surface area (h) | Largemouth bass Number caught | Largemouth bass Weight (kg) | Bluegill Number caught | Bluegill Weight (kg) | Channel catfish Number caught | Channel catfish Weight (kg) | Other catfish[3] and/or bullheads Number caught | Other catfish[3] and/or bullheads Weight (kg) | Crappie[4] Number caught | Crappie[4] Weight (kg) | Other[5] Number caught | Other[5] Weight (kg) | Totals Number caught | Totals Weight (kg) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1960........ | 56 (15) | 10,870 | 187 | 1,393 | 1,172 | 28,650 | 2,521 | – | – | 9,368 | 1,705 | 7,815 | 836 | – | – | 47,226 | 6,234 |
| 1961........ | 81 (37) | 9,896 | 151 | 2,207 | 1,920 | 57,640 | 5,418 | – | – | 19,973 | 5,752 | 55,564 | 14,780 | – | – | 135,384 | 27,870 |
| 1962........ | 77 (37) | 9,752 | 141 | 2,717 | 2,236 | 36,618 | 2,380 | – | – | 5,300 | 1,675 | 727 | 307 | – | – | 45,362 | 6,598 |
| 1965........ | 80 (76) | 10,756 | 165 | 3,702 | 3,139 | 24,922 | 2,093 | 1,782 | 1,105 | 1,301 | 398 | 13 | 11 | 201 | 29 | 31,921 | 6,775 |
| 1966........ | 70 (67) | 12,144 | 212 | 3,836 | 3,073 | 87,362 | 7,863 | 1,661 | 1,541 | 869 | 279 | 4 | 2 | 193 | 83 | 93,925 | 12,841 |
| 1967........ | 73 (31) | 17,855 | 234 | 7,484 | 5,853 | 59,224 | 5,982 | 4,080 | 4,459 | 939 | 300 | 32 | 18 | 203 | 170 | 71,962 | 16,782 |
| 1968........ | 76 (20) | 17,470 | 193 | 7,363 | 6,884 | 62,430 | 5,744 | 5,233 | 4,532 | 461 | 166 | 68 | 49 | 202 | 188 | 75,757 | 17,563 |
| 1969........ | 84 (84) | 13,909 | 381 | 5,672 | 5,059 | 41,110 | 3,330 | 3,783 | 3,465 | 229 | 87 | 136 | 72 | 178 | 195 | 51,108 | 12,208 |
| 1970........ | 79 (79) | 20,606 | 355 | 7,603 | 6,888 | 80,432 | 11,663 | 5,686 | 4,890 | 112 | 53 | 309 | 144 | 237 | 362 | 94,379 | 24,000 |
| 1971........ | 78 (78) | 18,953 | 242 | 6,898 | 6,319 | 13,552 | 1,992 | 5,668 | 4,619 | 78 | 32 | 2,966 | 1,653 | 109 | 330 | 29,271 | 14,945 |
| 1972........ | 99 (99) | 20,297 | 167 | 6,112 | 6,962 | 4,453 | 347 | 7,183 | 6,177 | 99 | 45 | 4,487 | 2,652 | 306 | 698 | 22,640 | 16,881 |
| 1973........ | 75 (75) | 14,910 | 270 | 5,289 | 4,972 | 6,996 | 504 | 4,200 | 2,545 | 61 | 22 | 1,202 | 791 | 254 | 549 | 18,002 | 9,383 |
| 1974........ | 67 (67) | 16,366 | 223 | 5,674 | 5,441 | 15,058 | 1,461 | 4,662 | 1,911 | 64 | 21 | 493 | 320 | 477 | 1,123 | 26,428 | 10,277 |
| 1975........ | 93 (93) | 23,105 | 187 | 9,140 | 7,714 | 2,989 | 203 | 4,330 | 2,282 | 57 | 12 | 12,927 | 4,718 | 2,168 | 3,328 | 31,611 | 18,257 |

[1] Data for 1960–62 from Fast (1966). Lee Miller collected census data (unpublished) in 1965 and 1966. Data for subsequent years was obtained as part of present study.

[2] Numbers in parentheses are the number of census days.

[3] Brown bullhead, black bullhead, yellow bullhead, and blue catfish, *Ictalurus furcatus*, present.

[4] Both black crappie *Pomoxis nigromaculatus*, and white crappie present.

[5] Others include green sunfish, carp, *Cyprinus carpio*, and golden shiner.

**APPENDIX 2. Annual Catch and Use Estimatees at Sutherland Reservoir, 1956–60, 1965 and 1966, and 1971–75.**

| | | | | *Largemouth bass* | | *Bluegill* | | *Channel catfish* | | *Other catfish[3] and/or bullheads* | | *Green sunfish* | | *Totals* | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Year[1]* | *Days open[2] to angling* | *Number of anglers* | *Mean surface area (h)* | *Number caught* | *Weight (kg)* | *Number caught* | *Weight (kg)* | *Number caught* | *Weight (kg)* | *Number caught* | *Weight (kg)* | *Number caught* | *Weight (kg)* | *Number caught* | *Weight (kg)* |
| 1956 | 35 (35) | 5,732 | 47 | 2,019 | 1,118 | – | – | – | – | 24 | 11 | 8,140 | 665 | 10,183 | 1,794 |
| 1957 | 63 (58) | 8,283 | 38 | 3,274 | 1,531 | 10 | 1 | – | – | 44 | 20 | 1,764 | 144 | 5,092 | 1,696 |
| 1958 | 59 (59) | 8,049 | 101 | 7,038 | 3,004 | 13,884 | 1,135 | – | – | 179 | 81 | 922 | 75 | 22,023 | 4,295 |
| 1959 | 68 (68) | 15,409 | 98 | 6,915 | 3,670 | 56,413 | 4,610 | – | – | 725 | 329 | 527 | 43 | 64,580 | 8,652 |
| 1960 | 113 (113) | 21,304 | 67 | 11,993 | 8,245 | 101,009 | 8,255 | – | – | 622 | 282 | 446 | 37 | 114,070 | 16,819 |
| 1965 | 87 (15) | 14,394 | 63 | 3,492 | 2,521 | 80,274 | 9,874 | – | – | 46 | 32 | – | – | 83,812 | 12,427 |
| 1966 | 81 (15) | 12,762 | 66 | 6,041 | 4,102 | 122,213 | 12,221 | – | – | 747 | 241 | 282 | 29 | 129,283 | 16,593 |
| 1971 | 66 (66) | 10,710 | 60 | 3,327 | 3,164 | 16,572 | 1,972 | 2,146 | 2,919 | 15 | 10 | – | – | 22,060 | 8,065 |
| 1972 | 75 (75) | 12,132 | 56 | 2,812 | 2,716 | 21,266 | 2,105 | 1,583 | 3,752 | 42 | 29 | – | – | 25,703 | 8,602 |
| 1973 | 87 (87) | 12,491 | 67 | 1,753 | 1,648 | 23,938 | 2,944 | 2,692 | 5,225 | 163 | 87 | 4 | 1 | 28,550 | 9,905 |
| 1974 | 102 (102) | 11,733 | 69 | 1,192 | 1,162 | 33,635 | 3,464 | 2,562 | 5,054 | 478 | 144 | 2 | – | 37,869 | 9,824 |
| 1975 | 86 (86) | 12,326 | 65 | 1,964 | 1,992 | 25,538 | 3,141 | 3,312 | 4,852 | 449 | 201 | 1 | – | 31,264 | 10,186 |

[1] Data from 1956 through 1960 from La Faunce, et al. (1964). Lee Miller collected census data (unpublished) in 1965 and 1966 Data for subsequent years obtained as part of present study.

[2] Numbers in parentheses are the number of census days.

[3] Brown bullhead dominant species taken.

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# RELATIVE ABUNDANCE STUDIES OF DUNGENESS CRABS, *Cancer magister,* IN NORTHERN CALIFORNIA [1]

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**A trawling study was initiated in January 1966 to determine the relative abundance of zero age class Dungeness crabs in Humboldt Bay. The study, completed in 1970, indicated that 1966 and 1968 year classes were very abundant compared to 1967 and 1969 classes. Scuba transects in Humboldt Bay and trawling outside the Bay supported the contention that the 1966 and 1968 year classes were strong. The scuba data indicated that trawls were missing about 50% of available crabs. Night trawling began in August 1968 to compare night and day catchability. Night catches were significantly larger.**

## INTRODUCTION

Annual landings of Dungeness crabs at ports from Fort Bragg to Crescent City have fluctuated widely since the inception of the trap fishery in the late 1930's. Catches have ranged from less than 1 million lb (450 Mg) during the 1973–74 and 1974–75 seasons to over 12 million lb (5400 Mg) during the 1958–59, 1967–68, 1968–69 and 1969–70 seasons (Figure 1).

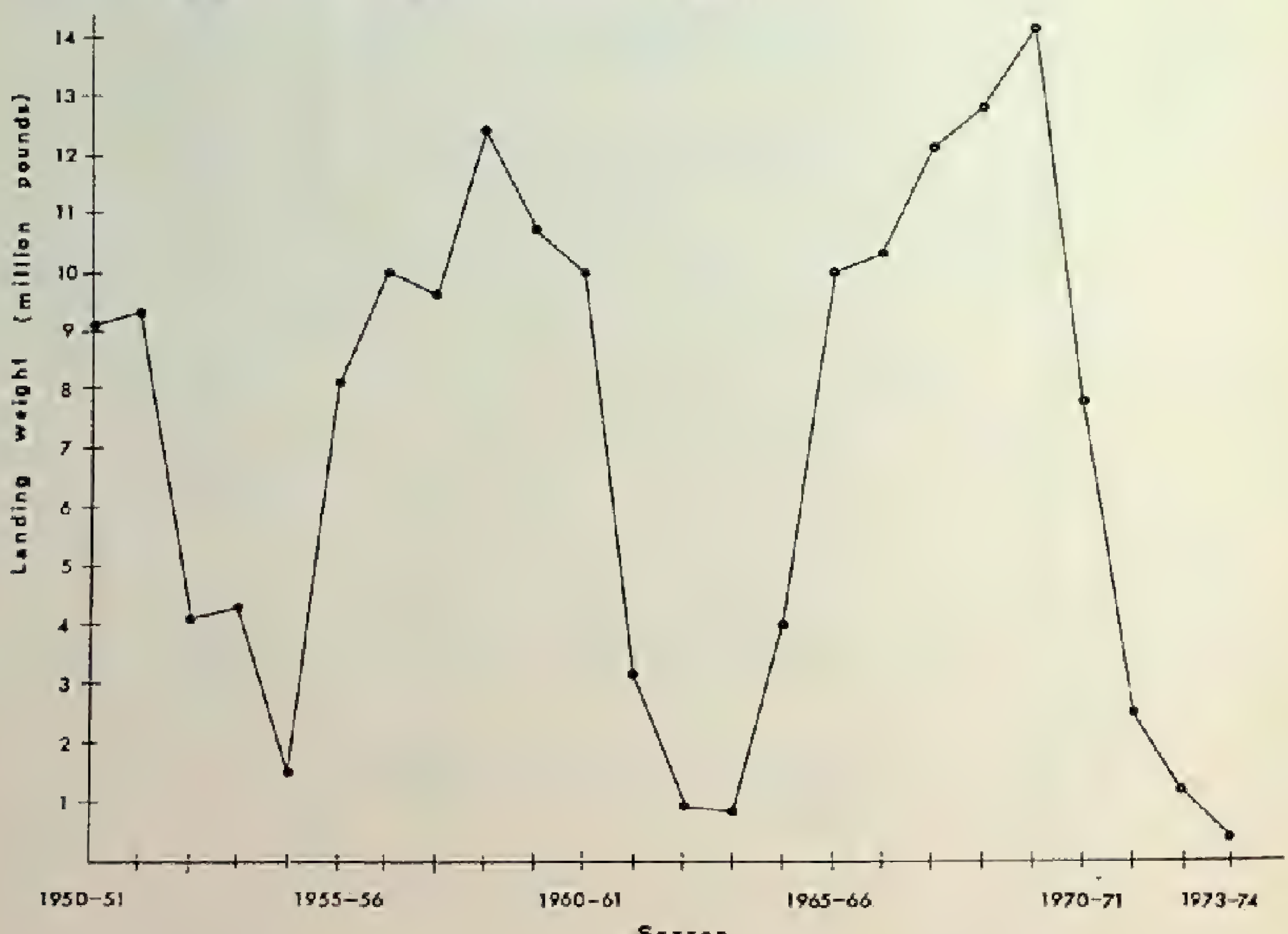


FIGURE 1. Northern California Dungeness crab landings—Fort Bragg to Crescent City, 1950–51 to 1973–74 seasons.

[1] Accepted for Publication March 1977.

From January 1966 through December 1969, Department of Fish and Game biologists conducted studies of the relative abundance of zero age class Dungeness crabs between False Cape and the Oregon border. Indices of abundance were developed for use in predicting numbers of legal-sized crabs 3 to 5 years in advance.

The ability to predict years of high and low abundance on a long term basis would be very valuable to the crab fishing industry in preparing for upcoming seasons.

Three different types of surveys were utilized in the study; trawling in Humboldt Bay, ocean trawling between False Cape and the Oregon border, and scuba diving on trawl study areas in the Bay.

## METHODS

Trawling was conducted in Humboldt Bay at several permanent stations (Figure 2) once per month. From January 1966 through July 1967, a 4.6-m (15-ft) skiff powered by a 18 horsepower outboard motor was used to tow a Gulf shrimp Try-net with a 4.9-m (16-ft) head rope and a 2.9-cm (1⅛-inch) stretch mesh. A liner of 1.3-cm (½-inch) stretch mesh was used in the cod-end. A 6.1-m (20-ft) ski barge with twin 18 horsepower outboard motors was used to tow the Try-net from July 1967 through December 1969. Trawling was conducted during daylight hours through July 1968. In August, night trawls were added to compare day to night catchability of juvenile crabs. From August through December 1969, all trawls were conducted at night.

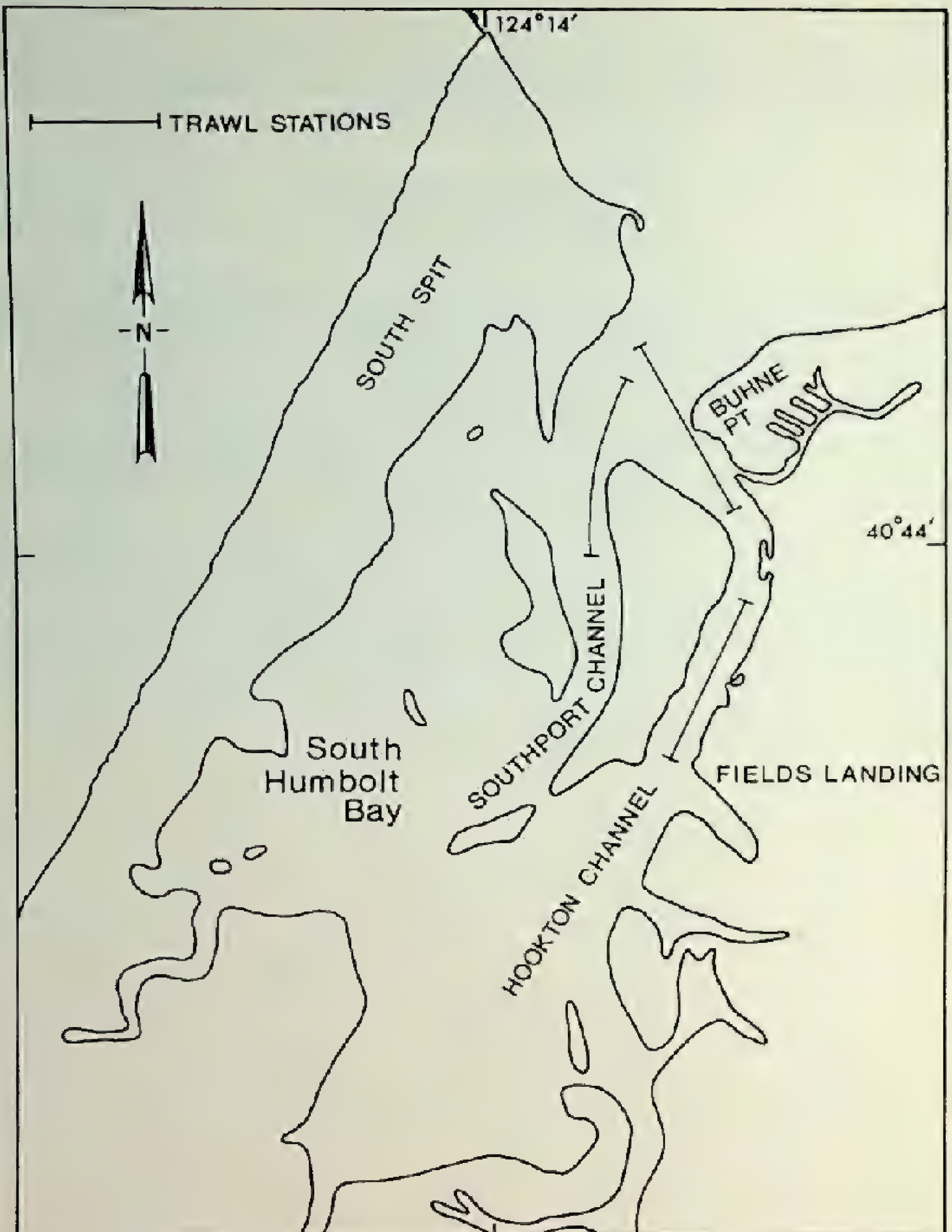


FIGURE 2. Location of trawling stations in South Humboldt Bay. Each station 0.8 km in length.

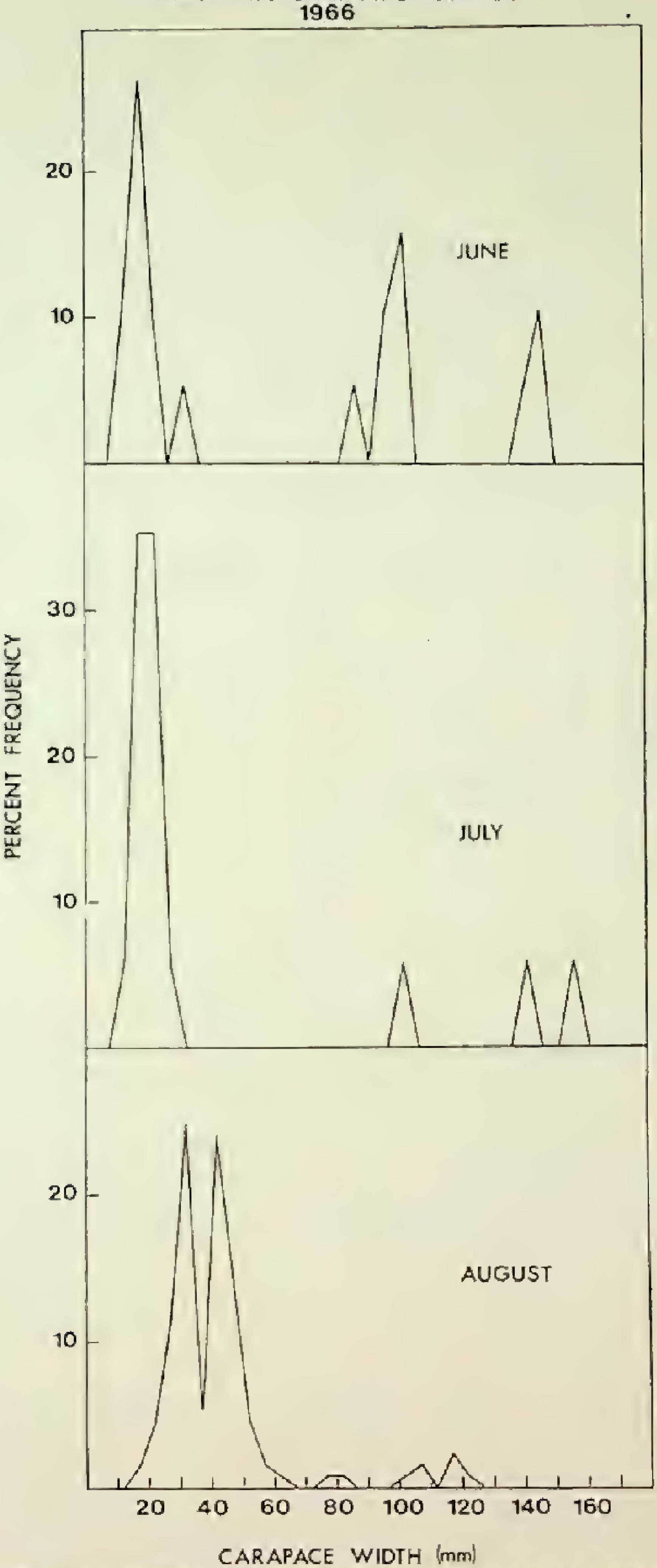


FIGURE 3. Example of carapace widths (5-mm groups) used in aging Dungeness crabs collected by trawl in Humboldt Bay, June through August 1966.

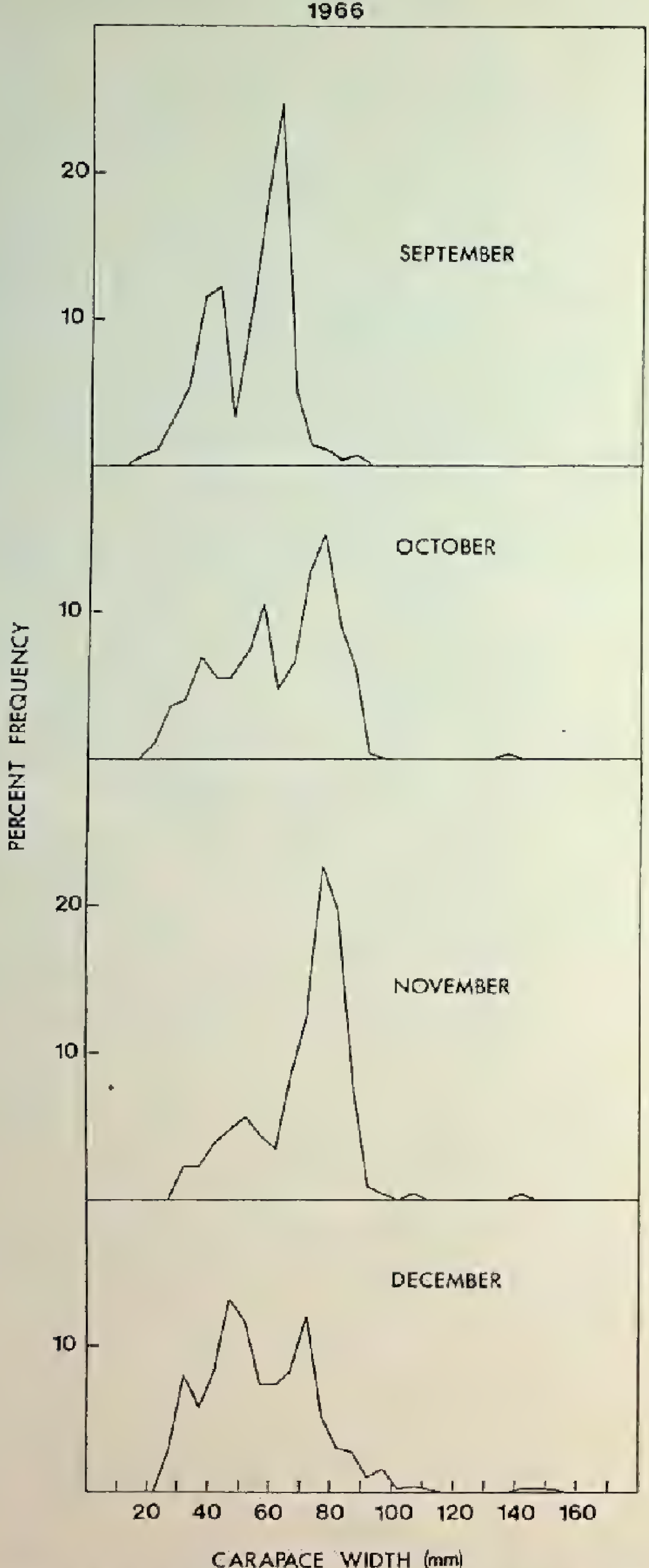


FIGURE 4. Example of carapace widths (5-mm groups) used in aging Dungeness crabs collected by trawl in Humboldt Bay, September through December 1966.

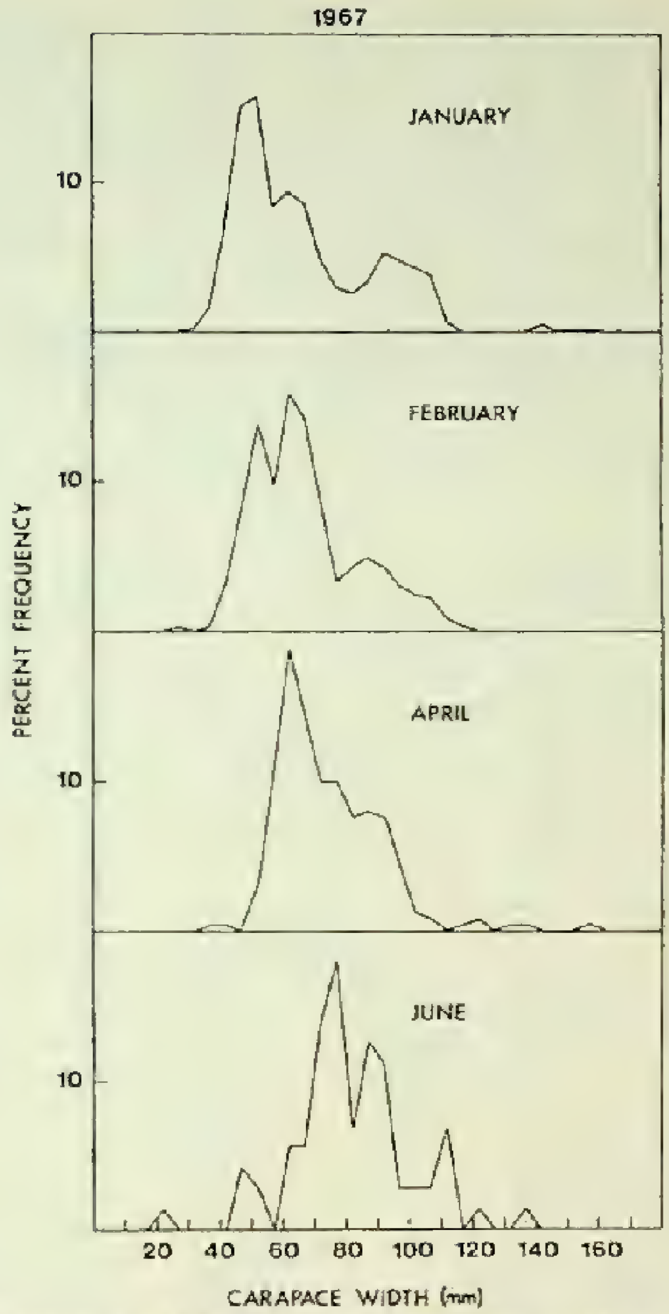


FIGURE 5. Example of carapace widths (5-mm groups) used in aging Dungeness crabs collected by trawl in Humboldt Bay, January through June 1967.

Three stations, each 0.8 km (0.5 miles) in length, were sampled once per month until November 1966; from then on we occupied only two of the stations. The stations were located as follows: Southport Channel, Hookton Channel west of Fields Landing, and Hookton Channel southwest of Buhne Point (Figure 2). The station west of King Salmon was abandoned in November 1966 because of lack of crabs.

Records were kept of the time the trawl was on the bottom and on numbers of each species of crab and fish caught. In most cases, all of the Dungeness crabs were measured (carapace width to nearest millimeter, excluding spines) and sexed. When large catches of Dungeness crabs occurred, a subsample was sexed and measured. Plotted carapace width frequencies were used to assign age classes; this method was accurate for crabs during their 1st year but questionable for crabs during their 2nd and 3rd years (Figures 3, 4, 5). No attempt was made to age crabs older than 3 years. Following Poole (1965), January 1st was the assigned birthdate.

Ocean sampling also involved trawling. Beginning in November 1966, trawls were made in conjunction with trap (commercial type crab traps) stations on

the Department's pre-season legal crab abundance surveys. All of these surveys since 1964 were conducted from the Department's research vessel *N.B. SCOFIELD,* except for the 1967 survey which was by charter of the commercial trawler/crabber, *K.D.M.* Trawling was conducted at randomly selected stations between False Cape and Point St. George in depths of 18 to 90 m (10 to 50 fm) (Figure 6). On the November 1969 survey, trawls were made along randomly selected east-west transects at 9-m (5-fm) intervals. A 12.5-m (41-ft) head rope Gulf shrimp trawl with 2.9-cm (1⅛-inch) stretch mesh was used. The trawl was towed for 0.8 km (0.5 mile). Records were kept similar to those for the Bay trawls.

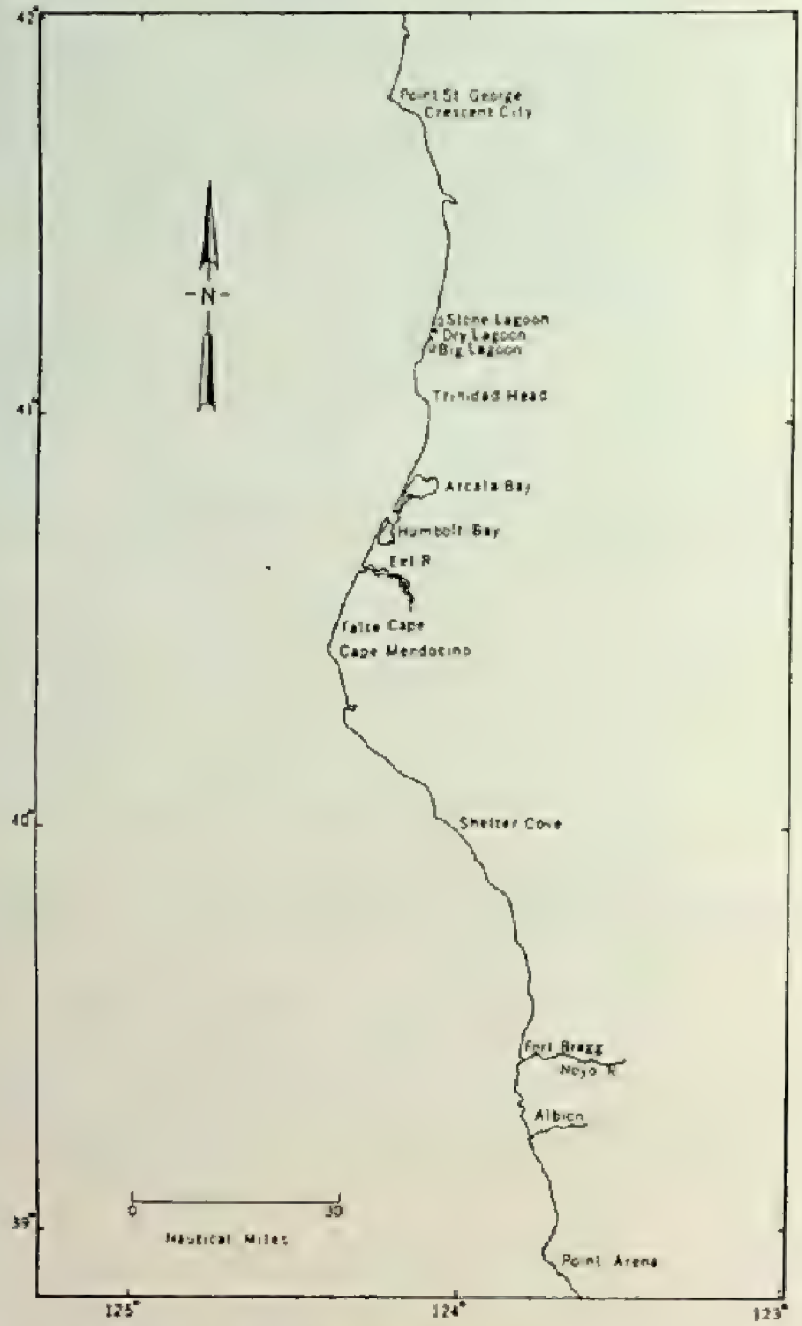


FIGURE 6. Northern California ocean trawling landmarks.

Another method of sampling Dungeness crabs involved the use of Department scuba divers. At randomly selected sites within the area encompassed by the Bay trawl stations, 30.5-x 4.6-m (100-x 15-ft) transects were surveyed. The divers, one on each side of a 30.5-m (100-ft) line, collected all visible crabs within reach, approximately 2.3 m (7.5 ft) either side of the line. Visible crabs, not collected because the divers were not able to catch them, were counted. Records were kept of underwater visibility, depth, temperature, type of sub-

strate, and general biological conditions (such as abundance of clam siphons). Crabs were brought to the surface, sexed and measured, then released. The number of transects completed on a particular day depended on weather and water conditions and endurance of the divers. The scuba surveys were conducted once per month as weather conditions permitted from August 1967 through October 1968.

## RESULTS

In the Bay trawling studies, 106 trawls were made from January 1966 through December 1969; 82 during daylight hours and 24 after dark. The catch consisted

**TABLE 1. Monthly Catch and Year Class of Dungeness Crabs in Humboldt Bay Trawls, January 1966–December 1969**

| Year | Month | Number of trawls | Number of crabs | Crabs per trawl | Year class composition 1964 | 1965 | 1966 | 1967 | 1968 | 1969 | Percent unclassified |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1966 | January | 3 | 325 | 108 | 15.7 | 81.5 | | | | | 2.8 |
| | February | 3 | 147 | 49 | 35.4 | 61.2 | | | | | 3.4 |
| | March | 3 | 165 | 55 | 13.3 | 86.7 | | | | | 0.0 |
| | May | 3 | 13 | 4 | 15.4 | 61.5 | 7.7 | | | | 15.4 |
| | June | 2 | 19 | 10 | | 31.6 | 52.6 | | | | 15.8 |
| | July | 2 | 17 | 8 | | 5.6 | 77.8 | | | | 16.6 |
| | August | 4 | 129 | 32 | | 51.9 | 48.1 | | | | 0.0 |
| | September | 3 | 164 | 55 | | 63.9 | 36.1 | | | | 0.0 |
| | October | 3 | 2,498 | 833 | | 52.9 | 46.4 | | | | 0.7 |
| | November | 2 | 1,394 | 697 | | 72.8 | 26.3 | | | | 0.9 |
| | December | 2 | 426 | 213 | | 40.2 | 58.9 | | | | 0.9 |
| 1967 | January | 2 | 2,357 | 1,178 | | 25.6 | 73.2 | | | | 1.2 |
| | February | 2 | 623 | 445 | | 15.8 | 84.2 | | | | 0.0 |
| | April | 2 | 691 | 346 | | 21.0 | 77.7 | | | | 1.3 |
| | June | 1 | 72 | 72 | | | 95.8 | 1.4 | | | 2.8 |
| | July | 2 | 153 | 76 | | | 88.0 | 12.0 | | | 0.0 |
| | August | 2 | 142 | 71 | | | 89.9 | 9.4 | | | 0.7 |
| | September | 2 | 0 | 0 | | | – | – | | | – |
| | October | 2 | 144 | 72 | | | 76.0 | 24.0 | | | 0.0 |
| | December | 2 | 114 | 57 | | | 43.1 | 56.9 | | | 0.0 |
| 1968 | January | 2 | 44 | 22 | | | 79.5 | 18.2 | | | 2.3 |
| | February | 2 | 195 | 98 | | | 21.3 | 78.7 | | | 0.0 |
| | March | 2 | 360 | 180 | | | 8.0 | 91.9 | | | 1.0 |
| | April | 2 | 67 | 34 | | | 20.9 | 77.6 | | | 1.5 |
| | May | 2 | 52 | 26 | | | | 3.9 | 96.1 | | 0.0 |
| | June | 2 | 540 | 270 | | | 1.7 | 1.5 | 96.1 | | 0.7 |
| | July | 2 | 23 | 12 | | | | 8.9 | 89.3 | | 1.8 |
| | August | 2 | 1,129 | 306 | | | | 1.4 | 97.3 | | 1.3 |
| | September | 4 | 145 | 36 | | | | 22.1 | 77.9 | | 0.0 |
| | October | 3 | 671 | 224 | | | | 6.0 | 93.0 | | 1.0 |
| | December | 4 | 2,255 | 565 | | | | 11.8 | 87.9 | | 0.3 |
| 1969 | January | 4 | 3,500 | 875 | | | | 1.9 | 98.0 | | 0.1 |
| | February | 4 | 2,337 | 584 | | | | 0.6 | 98.9 | | 0.5 |
| | March | 4 | 1,058 | 264 | | | | 1.8 | 97.6 | | 0.6 |
| | April | 3 | 1,006 | 335 | | | | 3.0 | 96.0 | | 1.0 |
| | May | 4 | 198 | 50 | | | | 5.6 | 92.4 | | 2.0 |
| | June | 4 | 181 | 45 | | | | 3.9 | 91.2 | 1.6 | 3.3 |
| | July | 4 | 38 | 10 | | | | | 13.5 | 73.0 | 13.5 |
| | August | 1 | 34 | 34 | | | | | 14.7 | 82.4 | 2.9 |
| | September | 2 | 23 | 12 | | | | | 8.7 | 69.6 | 21.7 |
| | December | 2 | 93 | 46 | | | | | 23.6 | 66.7 | 9.7 |
| TOTALS | | 106 | 22,769 | 214 | | | | | | | |

of 22,769 Dungeness crabs (Table 1). Numbers of crabs-per-trawl ranged from 1,178 in January 1967 to zero in September 1967. The overall mean number of crabs-per-trawl during the 4-year study was 214. Two strong incoming (zero age class) year classes were observed, the 1966 and 1968 year classes. Maximum catch-per-trawl values for these year classes of 862 and 858 occurred in January 1967 and January 1969, respectively. The 1967 and 1969 year classes were weak, yielding maximum catch-per-trawl values of only 165 (March 1968) and 31 (December 1969), respectively. The maximum catch-per-trawl values for all incoming year class crabs generally occurred during their first winter of life: January 1967 for the 1966 year class, March 1968 for the 1967 year class, January 1969 for the 1968 year class and December 1969 for the 1969 year class. However, the maximum value for the 1965 year class occurred in November 1966.

Catch-per-trawl values for the 1965 year class decreased to a low of about one per trawl in July 1966, then increased again to a high of 441 crabs per trawl in October 1966. The 1967 and 1968 year classes also followed the same pattern; the 1967 year class reaching a low of one crab per trawl in May and June 1968, then increasing in abundance to 67 crabs per trawl in December 1968. July and September 1969 were the low catch-per-trawl months for the 1968 year class, but this value increased again in December 1969 (Table 1). Apparently the crabs moved out of the survey area in South Humboldt Bay, possibly out of the entire Bay during their second summer of life, returning again during their second winter; or merely avoided the trawl.

Zero age class crabs were collected on five of six ocean trawling surveys (Table 2). Generally, the 1966 and 1968 year classes produced the highest catch-per-trawl values, while the 1967 and 1969 year class yielded relatively low values. Although the 1968 year class yielded the highest catch-per-trawl value in November 1968, this year class was not strongly represented in 31 trawls during early October 1968. Probably the crabs were not in the area trawled during October.

**TABLE 2. Catch-per-unit-of-Effort of Zero Age Class Dungeness Crabs in Six Trawl Surveys Between False Cape and Pelican Bay, 1966–1969.**

| *Survey dates* | *Total trawls* | *No. incoming year class crabs* | *Crabs per trawl* | *Survey depth range (m)* |
|---|---|---|---|---|
| Nov. 22–Dec. 3, 1966 | 30 | 9,100 | 303 | 25–62 |
| Nov. 11–Nov. 19, 1967 | 36 | 0 | 0 | 18–128 |
| Oct. 4–Oct. 9, 1968 | 31 | 99 | 3 | 25–88 |
| Nov. 4–Nov. 16, 1968 | 80 | 42,618 | 533 | 22–90 |
| Oct. 25–Nov. 3, 1969 | 55 | 507 | 9 | 18–201 |
| Totals | 232 | 52,324 | | |

On ocean surveys the variation between the catch-per-trawl values was large. For example, individual trawl catches ranged from 0 to 6,240 crabs on the September-October 1968 cruise; the November 1968 trawl catches varied from 0 to 24,000.

A total of 43 transects was completed by scuba divers in Southport Channel and Hookton Channel in Humboldt Bay from August 1967 through October 1968 (Table 3). The divers captured and observed 561 Dungeness crabs. Underwater visibility ranged from 0.6 to 6.1 m (2 to 20 ft) during the surveys. Divers found

that crabs were easier to approach during periods of low visibility. On one transect in Southport Channel the divers found crabs hiding beneath clam shells that littered the bottom; areas such as this probably would allow a high degree of escapement from trawl nets. Contrary to the bay trawl results, crabs were most abundant during August and September. The 1968 year class was the most abundant incoming year class encountered (Table 3).

**TABLE 3. Numbers, Sex Composition, and Year Class Composition of Dungeness Crabs Observed by Scuba Divers on Transects in Humboldt Bay, August 1967—October 1968.**

| *Month* | *Number of transects* | *Estimated visibility (m)* | *Number of crabs caught* | *Escaped* | *Crabs per transect* | *Percent Male* | *Percent Female* | *Year class com. (%) 1966* | *1967* | *1968* |
|---|---|---|---|---|---|---|---|---|---|---|
| 1967 | | | | | | | | | | |
| August* | 7 | — | 30 | 21 | 7.3 | 46.7 | 53.3 | 56.7 | 43.3 | |
| September | 8 | 0.6–1.2 | 3 | 0 | 0.4 | | 100.0 | 66.7 | 33.3 | |
| November | 5 | 0.9–1.8 | 3 | 0 | 0.6 | | 100.0 | | 100.0 | |
| 1968 | | | | | | | | | | |
| March | 3 | 0.6–1.2 | 2 | 0 | 0.7 | 50.0 | 50.0 | | 100.0 | |
| April | 4 | 0.9–1.8 | 0 | 0 | 0.0 | | | | | |
| August | 5 | 1.2–6.1 | 131 | 183 | 62.8 | 46.1 | 53.9 | | | 100.0 |
| September | 6 | 0.9–3.7 | 85 | 99 | 30.7 | 61.3 | 38.7 | | | 100.0 |
| October | 5 | 0.6–1.2 | 20 | 0 | 4.0 | 45.0 | 55.0 | | | 100.0 |
| Totals | 43 | | 274 | 303 | 13.4 | | | | | |

* Four transects off Buhne Point and South Jetty.

## DISCUSSION

Questions come to mind regarding the efficiency and validity of the methods studied. Are all crabs in the path of the net captured, or are the divers capturing or counting all of the crabs in the area covered by the transect? By comparing the density of crabs from trawls and scuba transects, the relative efficiency of trawls and scuba divers can be estimated.

The 4.9-m (16-ft) head rope Try-net had an estimated 3.0-m (10-ft) wide opening; thus the area swept by the trawl in 0.8 km (0.5 miles) would be about 2400 $m^2$ (25,820 $ft^2$).

The scuba divers surveyed 140.3 $m^2$ (1509 $ft^2$) on each transect. Using these two areas and the number of crabs caught and observed, calculations were made for the density of crabs-per-square-meter by month for the scuba data and for the same months from the bay trawl data (Table 4). Scuba transects in four out of seven cases yielded higher densities of crabs than the trawls. The exceptions were March, April, and October 1968. The overall density ratio between the crabs observed by the divers and those caught in the trawl was 2.2. In other words, for every 10 crabs captured by the trawl in this study, 12 more probably escaped.

**TABLE 4. Mean Number of Crabs per Square Meter (Density) as Shown by Trawl Catches and Scuba Surveys in Humboldt Bay, August 1967–October 1968.**

| | Bay trawls* | | | | Scuba** | | | |
|---|---|---|---|---|---|---|---|---|
| *Month* | *Number of trawls* | *Area swept ($m^2$)* | *Number of crabs* | *Crabs per $m^2$* | *Number of scuba transects* | *Area surveyed ($m^2$)* | *Number of crabs* | *Crabs per $m^2$* |
| 1967 | | | | | | | | |
| August | 2 | 4,800 | 142 | 0.030 | 7 | 982.1 | 51 | 0.052 |
| September | 2 | 4,800 | 0 | 0.000 | 8 | 1122.4 | 3 | 0.003 |
| 1968 | | | | | | | | |
| March | 2 | 4,800 | 360 | 0.075 | 3 | 420.9 | 2 | 0.005 |
| April | 2 | 4,800 | 67 | 0.014 | 4 | 561.2 | 0 | 0.000 |
| August | 2 | 4,800 | 613 | 0.128 | 5 | 701.5 | 314 | 0.448 |
| September | 4 | 9,600 | 145 | 0.015 | 6 | 841.8 | 184 | 0.218 |
| October | 3 | 7,200 | 671 | 0.093 | 5 | 701.5 | 20 | 0.028 |
| Totals | 17 | 40,800 | 1,998 | 0.049 | 38 | 5,331.4 | 574 | 0.108 |

* Area swept by trawl—2400 $m^2$

** Area swept by scuba divers—140.3 $m^2$

Divers often commented on the ability of crabs to escape them during periods of high visibility, or that crabs were not seen when clam shells or other objects were present for crabs to hide under. It would also follow that the crabs would attempt to escape from the net if they could see it approaching. The fact that the best trawl catches occurred during winter months when underwater visibility is generally lower and scuba divers observed more crabs in the summer, indicates that more crabs were escaping the net during periods of good visibility.

In August 1968 trawls were made at night and during the day to determine if sampling at night would yield results which were closer to actual abundance. A total of 24 night trawls were made at the two permanent stations in Southport and Hookton Channels between August 1968 and December 1969. Six pair of replicate night and day trawls were available for a test of significance; only trawls conducted on the same day and in the same area were used. The paired "t" test (Snedecor 1956) was used to test the null hypothesis, i.e. that there was no difference in catch-per-trawl values between night and day trawls, with the alternate hypothesis that more were caught at night. The calculated "t" value was 2.38, thus the null hypothesis was rejected at the 95% level using a one-tailed test. The average catch-per-trawl for the six night trawls was 263 crabs, while the six day trawls yielded a mean catch of 150 crabs. The ratio of apparent abundance (1.75:1) approached that of scuba divers to day trawls (2.2:1). Evidently crabs escape the trawl more easily during daylight hours. There was little difference between night and day trawls in terms of year class composition.

Availability during various times was an obvious factor affecting catches of crabs in survey areas. In most cases trawling was down-current, but what effect, if any, did an incoming or outgoing tide have on the number of crabs available to the net? From Southport Channel and Fields Landing Channel catch data, summations were made of all crabs caught on incoming and outgoing tides (Table 5). Outgoing tides produced distinctly higher mean catches of crabs-per-trawl at both stations. It seems likely that crabs move towards the center of the channels as the tide recedes.

**TABLE 5. Catch-per-Trawl of Dungeness Crabs on Incoming and Outgoing Tides, Southport Channel and Fields Landing Channel.**

| | *Southport Channel* | | *Fields Landing Channel* | |
|---|---|---|---|---|
| | *Incoming tides* | *Outgoing tides* | *Incoming tides* | *Outgoing tides* |
| Total crabs | 3,441 | 6,141 | 2,999 | 5,715 |
| Number of trawls | 18 | 17 | 15 | 21 |
| Mean number of crabs per trawl | 191.2 | 361.2 | 199.9 | 272.1 |

A comparison of indices calculated from bay trawls with northern California commercial landings from the season the crabs would be expected to enter the fishery provides some insights into the validity of the indices. Indices were calculated by correcting monthly mean daytime catch-per-trawls to conform to the higher catches made at night by multiplying the monthly daytime means by 1.75. Recent studies indicate that most northern California Dungeness crabs reach the legal size of 159 mm (6¼ inches) carapace width after 3.5 years (Ron Warner, pers. commun.). Using January as the birthdate, most of the 1965 year class would enter the fishery during the 1968–69 season, and the 1966 year class would enter the fishery during the 1969–70 season.

The landings for the 1968–69 season for northern California ports (Eureka to Crescent City) amounted to 5.3 million kg (11.7 million lb). The corrected mean catch-per-trawl inside Humboldt Bay (index) of 1965 year class crabs for the period January through June 1966 (arbitrarily selected because it was period of highest catches) was 38.5 crabs. The 1969–70 season landings through June 1970 were 6.1 million kg (13.4 million lb); the mean catch-per-trawl for the 1966 year class from January 1967 through June 1967 was 714.0 crabs. Landings during the 1970–71 season decreased to 3.3 million kg (7.2 million lb). The mean catch-per-trawl for 1967 year class crabs was 80.5. Landing data for the 1971–72 season show a decrease to less than 1.4 million kg (3 million lb), but the mean catch-per-trawl for the 1968 year class was 508.8 (Figure 7).

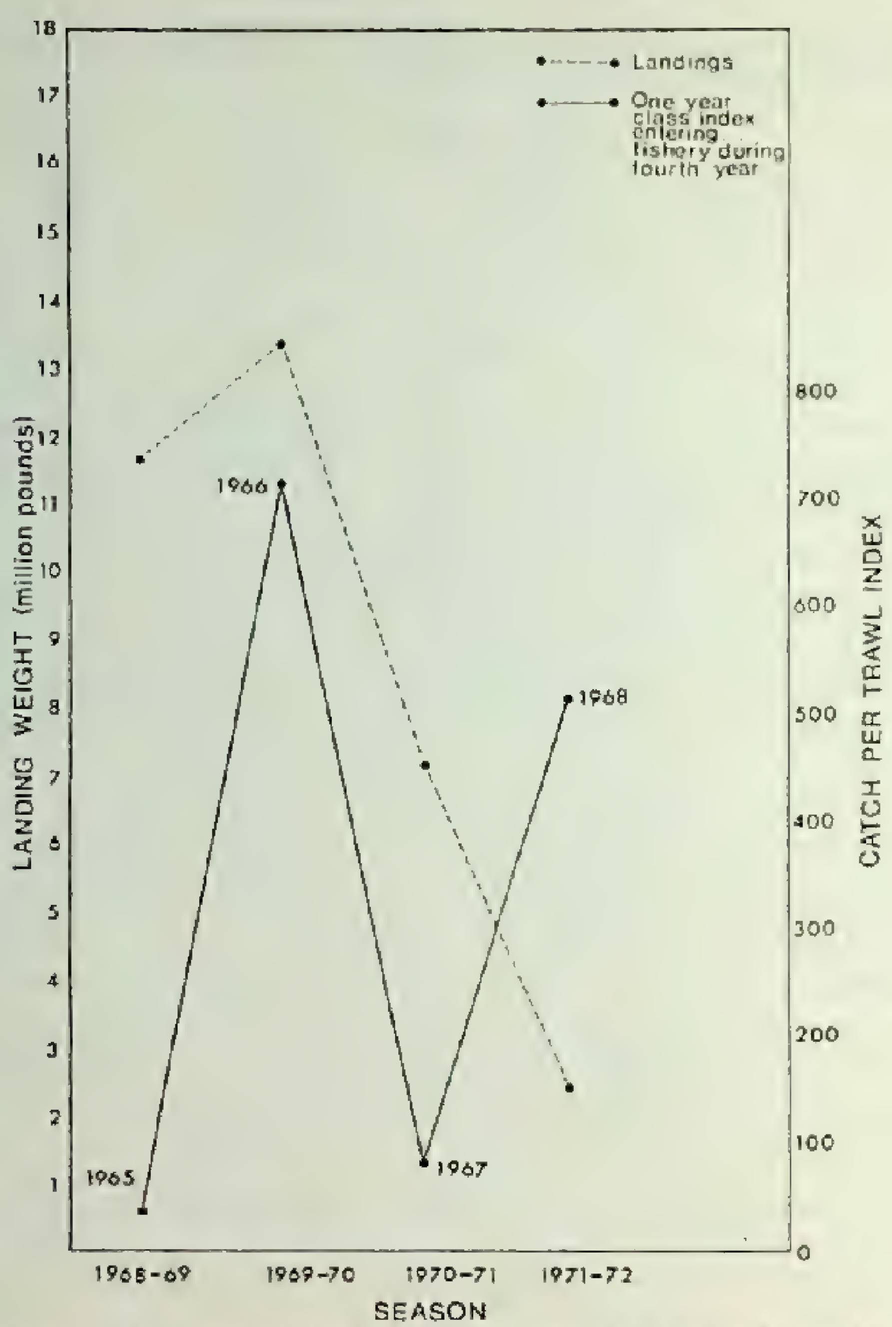


FIGURE 7. Comparison of Dungeness crab catch-per-trawl indices for incoming year class crabs, with commercial landings from Eureka to Crescent City 3.5 years later.

As indicated earlier, the ocean trawling paralleled the bay trawling results, i.e., indicating a weak 1967 and 1969 zero age class and a strong 1966 and 1968 year class. The scuba transects also indicated a weak 1967 year class and a strong 1968 year class.

The wide discrepancy between the mean catch-per-trawl values and annual landings particularly for the 1968 year class and the annual landings of 1.2 million kg (2.5 million lb) for the 1971–72 season could be due to a number of factors: the assumption that a particular year class contributes to the fishery for only one season probably is incorrect. It seems more likely that faster growing members of a particular year class could contribute significantly to the catch for at least 2 years, particularly if there was a large survival of legal-sized males at the end of the first season. There is also some evidence from food habit studies that large numbers of adults may seriously restrict the survival of the incoming year class due to the foraging on juveniles by the adults (Gotshall 1977). This fact alone could explain why the apparently very abundant 1968 year class did not produce

a large yield. Finally, sampling errors cannot be ruled out as to their effect, particularly in view of the limitations of the study in terms of space and time.

Despite the fact that this study produced valid indices for only two of the four year classes studied, I believe that with refinement of technique, useful and relative indices can be obtained by any one of the three methods tested. All three methods indicated a strong 1966 and 1968 year class and a weak 1967 year class. The indices might be more meaningful if the year class composition of each season's commercial catch could be determined.

I suggest that trawling outside Humboldt Bay be conducted to determine areas where juvenile crabs might be concentrated, such as around the mouths of large rivers. A multi-year study (minimum 5 years) should be initiated with standardized methods, i.e. bay trawling should be conducted during the same part of the tidal cycle and at night; ocean trawling should be conducted also at night at randomly selected stations. The indices obtained from this study can then be compared with commercial landings. In addition, the indices could be correlated with physical, chemical, and biological factors (for example density of adult crabs) to determine, if possible, causes of low survival.

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# FAWN PRODUCTION AND SURVIVAL IN THE NORTH KINGS RIVER DEER HERD [1]

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**The North Kings River deer herd has declined in size by over 50% in the last decade. The principal symptom of the decline has been low recruitment of new adults into the herd. This study was designed to determine the reproductive potential of the herd, and factors contributing to low recruitment. Over 100 does collected between 1971–1975 showed that fawn production potentials are high. Concurrent studies of coyote scats and herd composition showed that up to 70% of the fawn crop dies within the first month of life. Winter fawn losses are minor. The reproductive performance of this herd, coupled with our knowledge of the role of late gestation and lactation period nutrition in post natal survival of cervids, lead us to hypothesize a maturing trend in plant communities on spring migration and early summer habitats as the ultimate cause of the herd's decline.**

## INTRODUCTION

The recent history of the North Kings River herd of California mule deer (*Odocoileus hemionus californicus*) is similar to that of many western deer herds. Herd size, reported buck harvest and fawn to doe ratios have declined markedly since the mid 1950's. These obvious changes in western deer range capacities have prompted many new investigations into mule deer reproductive ecology (Gill and Swope 1972, Pederson 1972, Browning et al. 1973, Evans 1975, Trainer 1975, Papez 1976, Salwasser 1976, Smith and Le Count 1976).

The North Kings River Deer Herd Fawn Production and Survival Study is California's major effort in this diffuse search for more knowledge about deer. The study began in 1971, as part of the herd's management plan (Winter et al. 1970). Its primary objectives were to determine when and where fawn mortality occurred, and to identify the factors causing high fawn loss. Secondary goals were to establish the breeding period and fertility of the two populations that comprise the herd. This paper discusses the results of investigations concerning herd fertility and recruitment, and the chronology and magnitude of subsequent fawn mortality.

## THE NORTH KINGS RIVER DEER HERD AND RANGE

The deer winter in oak-grassland and chaparral vegetation (Munz and Keck 1959) at 360–1,100 m (1,200–3,600 ft) elevation (Bertram and Rempel 1977). Matriarchal family groups and buck groups are the common winter social structure of the herd. Depending on seasonal weather, the deer begin migrating to

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summer ranges in late March to late May. The herd does not move en masse, rather each family group moves on its own along its traditional migration corridor. This is similar to other migratory deer herds (Leopold et al. 1951, Ashcraft 1961, Gruell and Papez 1963, Robinette 1966, Jordan 1967).

Deer begin arriving on summer habitats of mixed conifer forest, seral brushfields, and sub-alpine meadows at 1,800–3,000 m, (6,000–10,000 ft) in May to early June. Family groups commonly disperse prior to fawning in late June, but reassemble toward mid summer. This is especially true of does unsuccessful in rearing fawns. Late summer storms force high elevation deer to move to lower summer ranges in September and October. The true fall migration, however, does not begin until the severe storms of October and November force most deer off the summer range. While spring migration may last up to 7 weeks for some family units, the fall return is often shorter. Radio monitored deer moved from summer to winter ranges in 2–3 weeks (Bertram and Rempel 1977). On both migrations deer show a tendency to delay in areas of favorable forage and cover. The breeding season commonly occurs in December, on the winter range.

Longhurst, Leopold, and Dasmann (1952) designated the herd boundary (Figure 1) and estimated 17,000 deer in the herd. Subsequent estimates, based on the Selleck and Hart (1957) change-in-ratio method, indicated a declining herd to 1973, and a stable to increasing herd in recent years (Figure 2). Figure 2 should be interpreted as representing general trends. Absolute numbers may be in error due to errors in the field data used to compute the estimates.

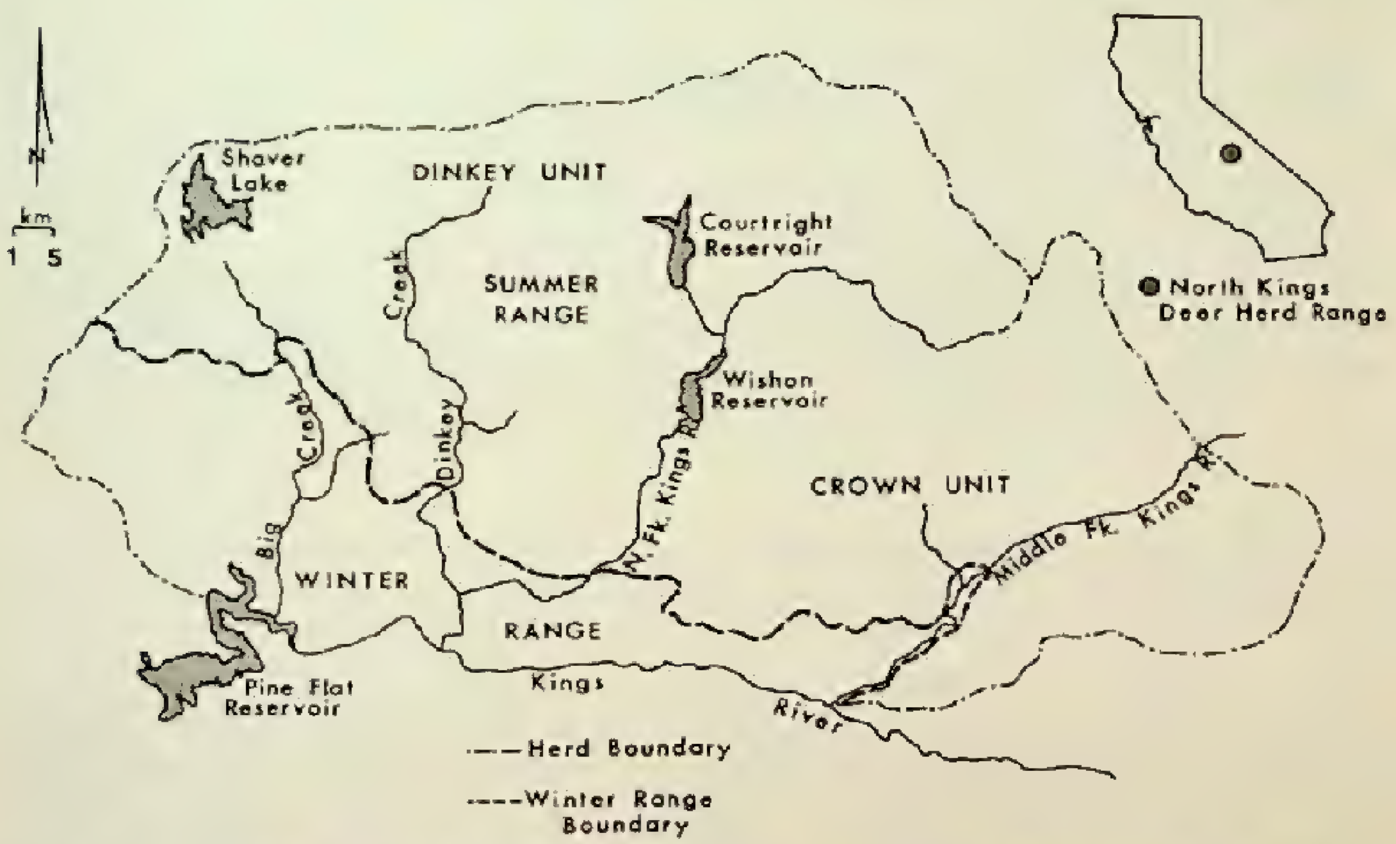


FIGURE 1. Boundary, seasonal ranges and sub-units of the North Kings River deer herd, Fresno County, California.

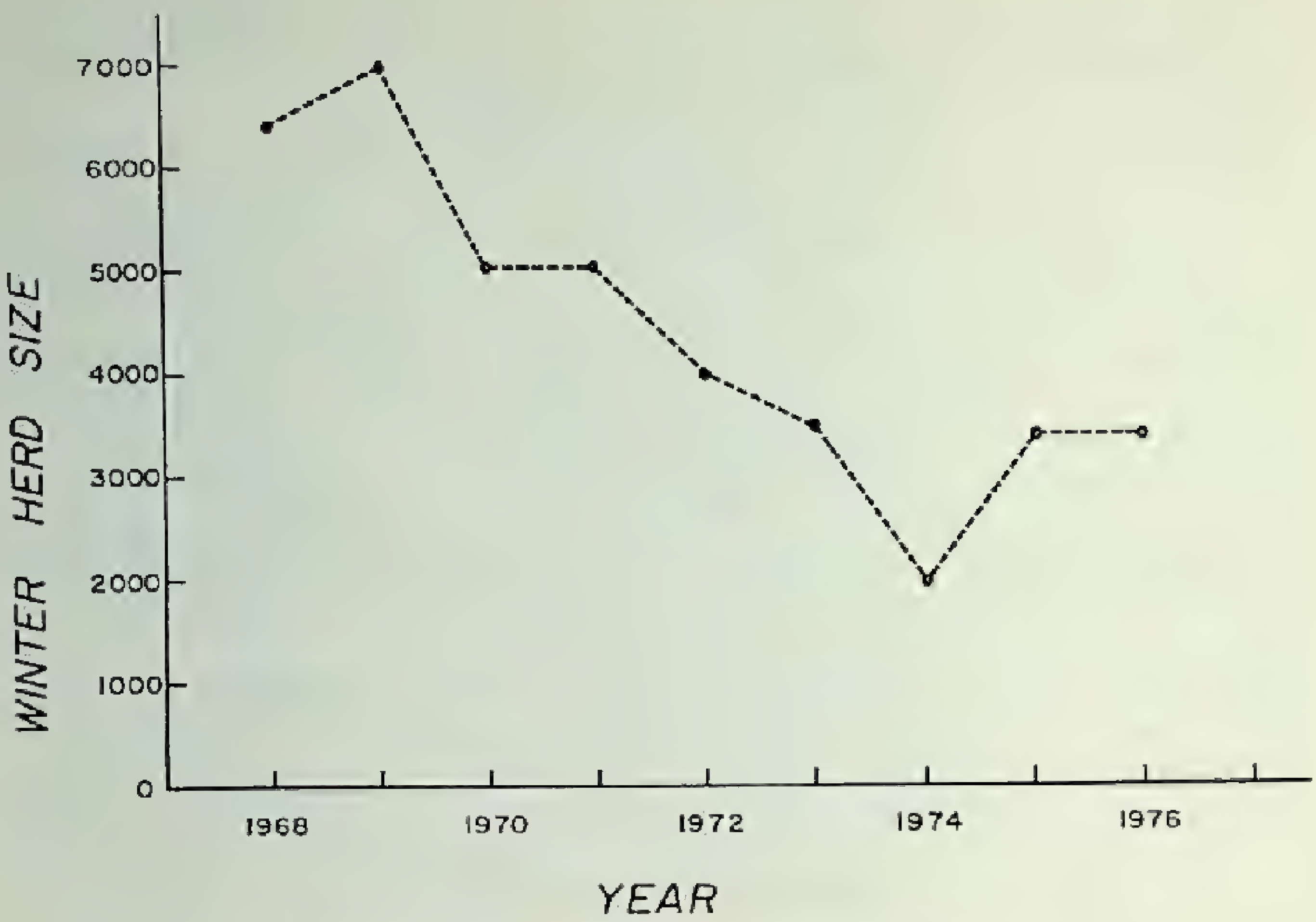


FIGURE 2. Estimated post winter size of the North Kings River deer herd.

Precipitation on the range occurs mainly from October to May. Average summer and winter range precipitation is presented in Table 1. Snow accumulates in winter regularly above 1,500 m (5,000 ft), and sporadically down to 360 m (1,200 ft). The first permanent snowpack of the year often occurs in November (11 of last 16 years at Wishon), and remains through early May. The first frost on the summer range often occurs by late September, and deer movements from higher elevation ranges appear to correlate with these early frosts.

**TABLE 1. Average Precipitation on the North Kings River Deer Range. Wishon Data 1945–1976. Trimmer data 1949–1976. Data given in centimeters.**

| *Station* | *J* | *F* | *M* | *A* | *M* | *J* | *J* | *A* | *S* | *O* | *N* | *D* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Wishon (1,996 m) (Summer range) (6550 ft) | 20.24 | 18.59 | 17.88 | 11.33 | 3.96 | 1.27 | 0.41 | 0.74 | 2.03 | 4.47 | 15.39 | 20.57 |
| Trimmer (224 m) (Winter range) (735 ft) .......... | 12.29 | 8.13 | 8.31 | 6.43 | 1.98 | 0.36 | 0.03 | 0.05 | 0.69 | 2.54 | 7.80 | 11.48 |

Principal forage competitors for the herd have been domestic sheep and cattle. Livestock grazing has occurred on the Sierra National Forest since the mid-1800's. Numbers peaked during the early 1940's at 18,000 cattle and 20,000 sheep. Sheep no longer graze the forest, and cattle allotments number 6,200. There are about 2,300 horses and mules allowed to graze the forest currently. Several investigations have been done, and are currently underway, on possible competition between cattle and deer (Pattee 1973).

Humans are the other major competitor. Recreation is the single largest use of the deer range, with at least 655,600 visitor days recorded in 1973. This is a marked increase from the early 1960's. Recreational hunting was 3.5% of the use, camping 33%, fishing 13%, and hiking 5%. Most human use occurs on summer ranges near meadows, lakes, and streams. It is coincident in July and August with the fawning and lactation periods of the deer. Some deer habitat may be precluded by this use, but the true impact on fawn survival is unknown.

Mountain lions, *Felis concolor,* coyotes, *Canis latrans,* bobcats, *Lynx rufus,* bears, *Ursus americanus* and golden eagles, *Aquila chrysaetos* are the major natural predators on the herd. Of these, only lions, coyotes and bears are considered capable of exerting a limiting force on the herd. This is not to say that any of the three has been shown to be limiting, however. In cover deficient areas, all three can readily take fawns and does. Densities of each predator population are unknown, but tracks, sightings, and spoor show them to be relatively common. The North Kings range lies between two potential population reservoirs for these species in Yosemite and Sequoia-Kings Canyon national parks.

Wildfire has been a major environmental influence on the range. It has been estimated that between the years of 1580 and 1920 wildfires occurred about every 8–9 years on many Sierra forest sites. Most fires on the Sierra National Forest are lightening started (61%) in the higher elevations. Rapid control usually limits them to less than .10 ha (1/4 acre). Man caused fires are potentially the most destructive as they often start during dry hot periods in lower elevation forests. There has not been a significant wildfire (40 or more acres) on the deer summer range in over 60 years. The average annual burned area on the range in the past 10 years is 38.5 ha (95 acres). Efficient control of wildfire and the past reluctance to use prescribed fire in vegetation management have reduced deer habitat rejuvenation to minor levels over the recent decades. This is currently being changed by new policies on the use of prescribed fire.

Logging has been another dominant factor in the North Kings ecosystem. Extensive logging began on private lands in the late 1800's, and by the 1940's the private forests had virtually all been logged. Most of these sites were on mid-elevation transitional habitats, and the brushfields that returned after logging were important migration habitats for many years. Much of this land is currently in second growth timber or decadent stands of brush. Currently 40.5–81 ha (100–200 acres) of private land on the ranges are logged annually. Logging on USFS lands adds about 405 ha (1,000 acres) to this total.

While successional processes alter deer range capacities in either a positive or negative manner, irreversible commitments of the land base to roads, reservoirs, campgrounds and second home development constitute permanent losses in range potentials. The North Kings deer range has three large reservoirs, built primarily for electrical power generation, on what used to be meadow and riparian summer habitats. There is one large reservoir on the winter range. New construction will add more people and campsites to summer range areas. Second home development near Shaver Lake continues to remove deer habitat every year. Land managers can do much to improve the productivity of wildland ranges, but the absolute potential will decline as a function of how much land is taken out of production by society. A conservative estimate of these losses on the North Kings range would amount to summer and winter habitat for 1,000 deer.

## METHODS

Deer were systematically collected for necropsy with a rifle. Fawns and bucks were avoided. Numerous persons assisted in the collections. Hence it is possible that sampling strategy varied according to personal interpretation of what was or wasn't a fawn. While this probably had little effect on a representative sample of 2-year and older does, the sample of yearling does is probably biased toward the largest of that age class.

Following collection, the deer were transported to a field laboratory for necropsy. The lower jaw was removed, and a preliminary age of the deer was assigned on the basis of molariform tooth wear compared to a known age jaw. Incisors were later sent to Gary Matson (Milltown, Montana) for sectioning and dental cementum ring counts. A combination of annular rings, Matson's judgment of their accuracy, and the tooth eruption and wear pattern was used to derive final age estimates. In most cases the annular ring count was used.

Ovaries were removed and fixed in a 10% formalin solution prior to sectioning. Sectioning was done with a razor blade or scalpel, and corpora lutea of pregnancy (CLP) were counted according to the method described by Teer, Thomas and Walker (1965). Each corpus luteum was considered to represent one ovum shed during the breeding period. Fetuses were removed and fixed in 10% formalin also. They were sexed by examination of external genitalia prior to storage.

Reproductive data was examined for between age and between year differences. Since only between age differences were consistent, the data from all 5 years were pooled into age groups. Statistics were calculated on the pooled data.

The chronology of fawn survival was estimated by observing changes in the herd's sex and age composition, and by determining the temporal pattern of fawn remains in coyote scats (Salwasser 1974). Since we lack knowledge of adult survival rates, the estimates of fawn survival are in fact estimates of fawn survival relative to adult survival. We use the term *relative fawn survival* to acknowledge this.

Semi-annual, post-harvest and post-winter, herd composition counts were taken in each year, using standard methods (California Department of Fish and Game 1957). The average fetal rate for the years 1971–1975, for yearling and older does was used to estimate potential fawn production by the formula: $P_f$ = Fetal rate $\times$ Potential breeding does per 100 does of all ages at fawning, where $P_f$ is the fawn production potential, and potential breeding does are estimated from the previous spring fawn to doe ratio; Potential breeding does per 100 does $= 100/(100 + \text{spring fawns per 100 does}/2) \times 100$. This equation assumes spring fawns are in equal sex ratio, that doe fawns do not breed, and that age differential mortality to females is insignificant after the spring herd composition count. We believe these assumptions are valid in this herd.

This method accounts for the influence of non-breeding fawns and normal non-pregnancy rates in the initial fawns per 100 does at birth. It thus allows a more meaningful and direct comparison of fawns per 100 does post-harvest, with the ratio at birth to estimate relative fawn mortality during the first 6 months of life. A critical element of the method is the knowledge of yearling fertility. If it differs greatly from older doe fertility, an allowance for

yearling contributions to the fawn crop would have to be added. With increases in knowledge and needs for detailed analyses, a more comprehensive age-specific fawn production model would have to be devised. The method described here is an adequate starting point.

Herd recruitment is estimated from observed post-winter herd age composition counts. Since we cannot calculate absolute recruitment of yearling deer into the adult population, we use a formula for *proportional adult recruitment;* $R_a$ = Fawns per 100 Adults/(100 + Fawns per 100 Adults) where $R_a$ is the proportional recruitment of new adults to the herd. This method assumes equivalent age and sex specific mortality between the time the count is made and the next birth pulse, at which time the previous year's fawns become yearlings and are considered as part of the adult herd. Accuracy of this method obviously depends on reliable estimates of true herd age ratios.

## RESULTS

Over the 5-year period 1971–1975, 102 adult does were collected during winter and spring. Annual sample sizes are listed in Table 2. The age structure of the pooled 5-year sample is illustrated in Figure 3. The structure, showing fewer yearlings than 2-year olds, indicates the possible sampling bias against small yearling does. A stable population would have had more yearlings than 2-year olds if our sample was unbiased. If the herd was actually declining in size such a structure is possible. However, we believe a sample bias against small yearlings is the more logical explanation of this structure. The herd was stable to increasing the last 3 years of study.

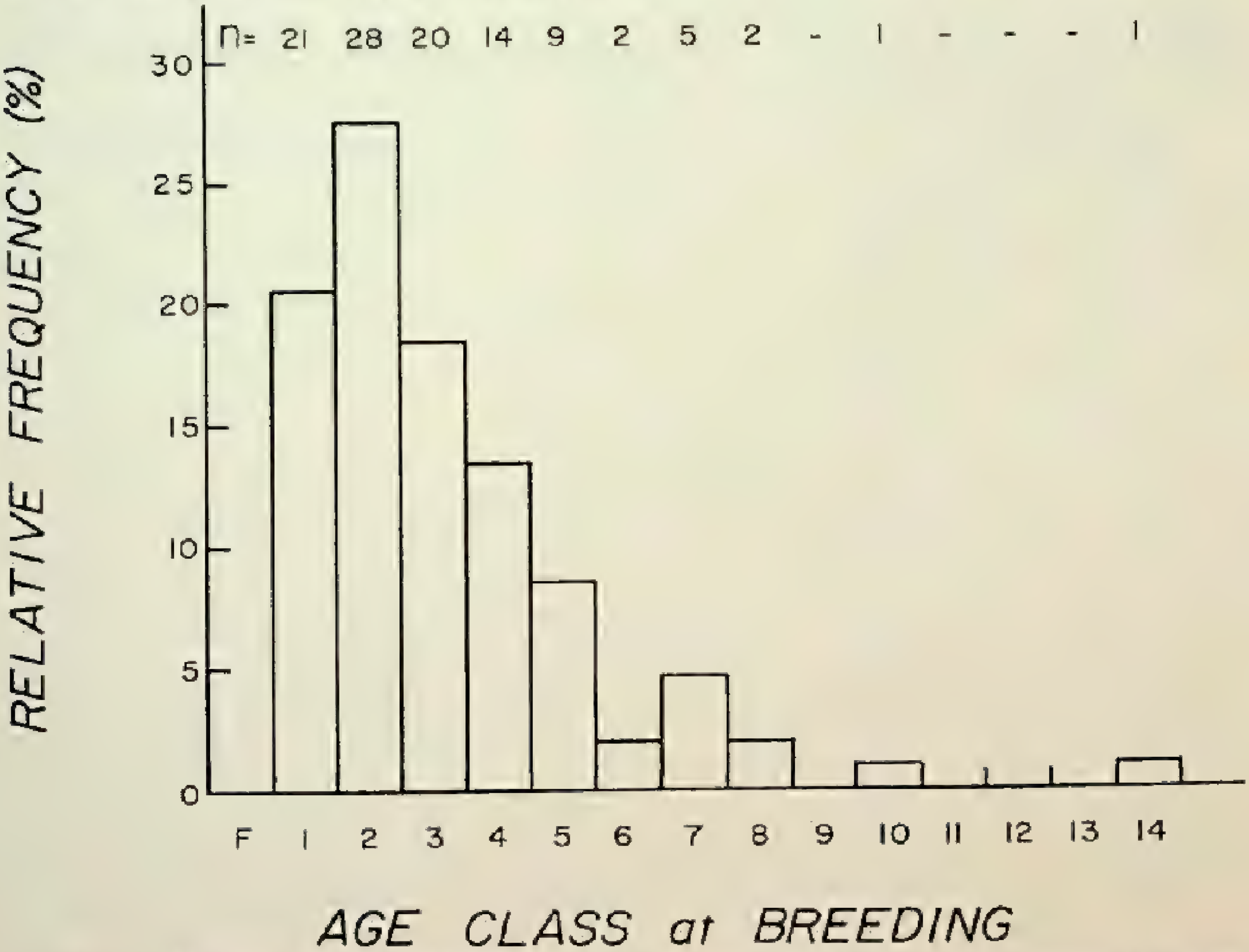


FIGURE 3. Age class structure of the 1971–1975 special collection sample of North Kings River female deer.

Due to small annual samples, annual herd structure changes cannot be inferred. The data indicate that few does live past 6 years of age. Although proportional adult recruitment differed slightly during study years, the age class histogram indicates about a 65-75% survival rate of does aged 2–5, and perhaps a lower, 30–50%, survival rate of does past age class five. Does in the herd appear to have about a 6-year turnover period.

**TABLE 2. Female Mule Deer Collected for Reproductive Studies on the North Kings River Herd in Fresno County, California, 1971–1975.**

| *Year* | *Age group* | *n* | *Year* | *Age group* | *n* |
|---|---|---|---|---|---|
| 1971 | Total | 20 | 1974 | Total | 19 |
| | Yearling | 4 | | Yearling | 4 |
| | 2–3 year | 8 | | 2–3 year | 8 |
| | 4 Year + | 8 | | 4 Year + | 6 |
| 1972 | Total | 17 | 1975 | Total | 27 |
| | Yearling | 2 | | Yearling | 6 |
| | 2–3 Year | 5 | | 2–3 Year | 14 |
| | 4 Year + | 10 | | 4 Year + | 7 |
| 1973 | Total | 19 | 1971–1975 | Total | 102 |
| | Yearling | 4 | | Yearling | 21 |
| | 2–3 Year | 12 | | 2–3 Year | 47 |
| | 4 year + | 3 | | 4 Year + | 34 |

**TABLE 3. Mean Ovulation Rates by Age Class of Mule Deer in the North Kings River Herd, Fresno County, California, 1971–1975**

| *Age class at breeding* | *Year* | *n* | *Mean CLP* | *Pooled mean ovulation rate* | | |
|---|---|---|---|---|---|---|
| | | | | *n* | *Mean* | *S.E.* |
| 1 Year | 1971 | 4 | 1.50 | | | |
| | 1972 | 2 | 1.50 | | | |
| | 1973 | 4 | 1.50 | | | |
| | 1974 | 5 | 1.00 | | | |
| | 1975 | 6 | 1.66 | 21 | 1.43 | .010 |
| 2 year | 1971 | 5 | 1.80 | | | |
| | 1972 | 3 | 1.33 | | | |
| | 1973 | 9 | 1.56 | | | |
| | 1974 | 5 | 2.20 | | | |
| | 1975 | 6 | 2.00 | 28 | 1.79 | .047 |
| 3 Year | 1971 | 3 | 1.33 | | | |
| | 1972 | 2 | 1.00 | | | |
| | 1973 | 3 | 2.00 | | | |
| | 1974 | 3 | 1.67 | | | |
| | 1975 | 8 | 1.88 | 19 | 1.68 | .052 |
| 4 + Year | 1971 | 8 | 1.75 | | | |
| | 1972 | 10 | 2.10 | | | |
| | 1973 | 3 | 2.00 | | | |
| | 1974 | 6 | 2.17 | | | |
| | 1975 | 7 | 2.14 | 34 | 2.03 | .036 |

Ovulation rates for age classes 4–14 do not appear to differ consistently, so those age classes are grouped into the category 4 + years (Table 3). Differences between yearling to 4 + year does are considered biologically significant. While there appears to be annual variation within an age class, these differences are probably due to sampling errors. Thus the pooled mean ovulation rates for the 5 years are interpreted as the best estimates of average rates for the respective age groups.

The yearling ovulation rate of 1.43 is high for this age class and may reflect our sample bias. Dauphiné (1976) and Verme (1969) found respectively that larger young caribou, *Rangifer tarandus,* and White-tailed deer (*O. virginianus)* have higher fertility rates than smaller females in the same age class. North Kings 2 and 3-year old does have intermediate rates at 1.79 and 1.68 respectively. Four year and older does averaged 2.03 ova shed per doe.

Annual and pooled fetal rates are listed in Table 4. Rates for 4–14 year old does do not differ consistently, so those age classes are grouped as for ovulation rates. The difference between yearling and 4-year + does is biologically significant. Annual differences within each age group are not consistent. The pooled means are thus used as the best estimates of fetal rates for the respective age groups.

The yearling fetal rate of 1.33 probably also reflects our bias towards large yearling does. Two and three years old does have intermediate fetal rates of 1.68 and 1.53, respectively, while 4-year + does averaged 1.85 fetuses per doe. Because of the minor differences between 2 and 3-year old does, their reproductive rates are pooled in further discussions. Table 5 presents the reproductive potential summaries for the 5 years of study.

**TABLE 4. Mean Fetal Rates by Age Class of Mule Deer in the North Kings River Herd, Fresno County, California, 1971–1975.**

| *Age class at breeding* | *Year* | *n* | *Mean fetal rate* | *Pooled mean fetal rate* *n* | *Mean* | *S. E.* |
|---|---|---|---|---|---|---|
| 1 Year | 1971 | 4 | 1.25 | | | |
| | 1972 | 2 | 1.00 | | | |
| | 1973 | 4 | 1.50 | | | |
| | 1974 | 5 | 1.00 | | | |
| | 1975 | 6 | 1.67 | 21 | 1.33 | .095 |
| 2 Year | 1971 | 5 | 1.80 | | | |
| | 1972 | 3 | 1.33 | | | |
| | 1973 | 9 | 1.44 | | | |
| | 1974 | 5 | 2.20 | | | |
| | 1975 | 6 | 1.67 | 28 | 1.68 | .057 |
| 3 Year | 1971 | 3 | 1.33 | | | |
| | 1972 | 2 | 1.00 | | | |
| | 1973 | 3 | 2.00 | | | |
| | 1974 | 3 | 1.00 | | | |
| | 1975 | 8 | 1.75 | 19 | 1.53 | .086 |
| 4 Year + | 1971 | 8 | 1.63 | | | |
| | 1972 | 10 | 2.00 | | | |
| | 1973 | 3 | 1.67 | | | |
| | 1974 | 6 | 1.83 | | | |
| | 1975 | 7 | 2.00 | 34 | 1.85 | .085 |

**TABLE 5. Reproductive Potential Summary of Mule Deer in the North Kings River Herd, Fresno County, California, 1971–1975.**

| *Age class at breeding* | *n* | *% Preg.* | *Ovul. rate* | *Fetal rate* | *% Fertility* | *% Twins* | *% Triplet* | *% Males* |
|---|---|---|---|---|---|---|---|---|
| 1 Year | 21 | 90% | 1.43 | 1.33 | 93% | 47% | 0 | 54% |
| 2–3 Year | 47 | 96% | 1.75 | 1.62 | 93% | 64% | 2% | 50% |
| 4 Year + | 34 | 94% | 2.03 | 1.85 | 91% | 72% | 13% | 52% |
| All does | 102 | 94% | 1.78 | 1.64 | 92% | 64% | 5% | 53% |

Over 90% of all does collected carried fetuses; 90% of yearlings, 96% of 2–3 year olds and 94% of 4-year and older does. Likewise, over 90% of ova shed were represented by fetuses *in utero;* 93% for does under 4 years, and 91% for older does. There was an increasing gradient of multiple litters with age of doe; 47% for yearlings, 66% fpr 2–3 year olds and 85% for older does. There was a slightly larger proportion of male fetuses to female fetuses in young and old does. We do not feel these differences are significant.

Reproductive potentials, computed by sub-unit within the herd are listed in Table 6. It is not possible to infer a real difference between the sub-units from these data. Sample sizes are too small on the Crown portion of the herd. There appears to be a higher reproductive potential in the Dinkey sub-unit. Both yearling and 4+ year does have higher fetal rates in Dinkey than in Crown. However, 2–3 year old does are higher in Crown. The most consistent difference between the units is the fertility rate. More ova are represented by fetuses in the Dinkey unit. On the other hand, there appears to be a lower pregnancy rate in the Dinkey unit. Such inconsistent data can only lead to development of hypotheses about differences between the sub-units. We believe the differences seen in Table 6 are due to sampling errors, and are not to real biological differences. Data from the two sub-units is pooled, as in Table 5, for further discussion.

**TABLE 6. Reproductive Potential Differences Between Sub-Units of the North Kings River Mule Deer Herd, Fresno County, California, 1971–1975.**

| *Age class at breeding* | *n* | *% Preg.* | *Mean CLP* | *Mean fetuses* | *% Fertility* |
|---|---|---|---|---|---|
| 1 Year | | | | | |
| Dinkey | 18 | 89% | 1.45 | 1.39 | 96% |
| Crown | 3 | 100% | 1.33 | 1.00 | 75% |
| 2–3 Year | | | | | |
| Dinkey | 37 | 95% | 1.71 | 1.59 | 93% |
| Crown | 10 | 100% | 1.90 | 1.70 | 89% |
| 4 Year + | | | | | |
| Dinkey | 27 | 93% | 2.07 | 1.93 | 93% |
| Crown | 7 | 100% | 1.86 | 1.57 | 84% |

Because yearling fetal rates are appreciably lower than those of older does, and we apparently biased our sample of yearlings to larger individuals, we adjusted the fawn production potential for all breeding age does downward from 1.64 (in Table 4) to 1.50. While this is an arbitrary number, it probably reflects the true herd potential more accurately than does 1.64.

The rate of 1.50 per breeding age doe was used to calculate fawn production potentials (Table 7). Also included are subsequent fawn to doe ratios counted in fall and spring, and the estimates of relative fawn survival based on those counts.

**TABLE 7. Reproductive Potentials, and Relative Fawn Survival in the North Kings River Mule Deer Herd, Fresno County, California, 1971–1975**

| *Year* | *Potential FF:100DD* | *Fall FF:100DD* | *Relative fawn survival to December* | *Spring FF:100DD* | *Relative fawn survival to March* | *Relative annual fawn survival* |
|---|---|---|---|---|---|---|
| 1971 | 129 | 32 | 25% | 30 | 94% | 23% |
| 1972 | 131 | 38 | 29% | 34 | 89% | 26% |
| 1973 | 128 | 63 | 49% | 58 | 92% | 44% |
| 1974 | 116 | 56 | 48% | 46 | 82% | 40% |
| 1975 | 122 | 55 | 45% | 43 | 78% | 35% |
| 5 Year Mean | 125 | 49 | 39% | 42 | 86% | 34% |

Two ecological factors are obvious: 1) most fawn mortality occurs in the herd prior to the start of winter, and 2) something changed dramatically in 1973. Because adult deer are surely dying between fawn drop and the fall count, the relative fawn survival of 25–49% during that time probably equates to no more than 20–40% real survival of the fawn crop. Salwasser (1974) documented that the greatest fawn losses in summer occur during and immediately after the fawning period. Thus the estimated summer fawn mortality of 60–80% is principally a neo-natal to post-natal loss. Fawn survival during winter is high. Therefore, annual recruitment of yearlings into the herd is largely dependent upon fawn survival through the post-natal period.

For 5 years leading into the study period, recruitment averaged 20% of the existing herd size (Figure 4). The herd declined under this rate. During the study period recruitment showed a slight increasing trend, from 23% in 1972–1973 to 25% in 1975–1976. The favorable year 1974, hit 32%. The herd was able to stabilize at about 3,500 deer under this recruitment rate. Recruitment would probably have to approach 30% on a sustained basis to result in a marked herd increase, and stability at a higher herd size.


FIGURE 4. Proportional recruitment of new adults into the North Kings River deer herd.

## DISCUSSION

The reproductive potential of the North Kings River herd is high relative to other herds reported in the literature (Table 8). It is higher than some Utah mule deer in the late 1940's (Robinette and Gashwiler 1950), the Antimony herd in Utah in the mid 1950's (Julander, Robinette, and Jones 1961), the Doyle herd in California in the 1950's (Lassen, Ferrel, and Leach 1952), the Railroad Flat herd in California in the 1970's (Browning, Schulenburg, and Brunetti 1973) and the Ruby Butte herd in Nevada in the 1970's (Papez 1976). It is lower than the Sublett herd of Idaho in the mid 1950's (Julander, Robinette, and Jones 1961). It compares favorably with other Utah herds (Robinette et al. 1955), the neighboring San Joaquin herd in California in the 1950's (Jordan 1967) the Bison Range mule deer in Montana in the 1960's (Nellis 1968), the Middle Park herd in Colorado in the 1970's (Gill and Swope 1972), the Steen's Mountain herd in Oregon in the 1970's (Trainer 1975) and the Devil's Garden herd of California and Oregon (Chattin 1948) and Salwasser 1976).

Mule deer fetal rates are quite variable from herd to herd, no doubt a reflection of intrinsic range differences as shown by Cheatum and Severinghaus (1950) for white-tailed deer, Taber and Dasmann (1957) for black-tailed deer (*O. hemionus columbianus*) and Julander, Robinette, and Jones (1961) for mule deer. The North Kings range ranks above average in fawn production among western mule deer ranges. This is especially indicated by the high yearling fetal rate.

It is obvious from this investigation that low adult recruitment in the herd is not a function of inadequate reproductive potential. This supports the findings of the other workers on mule deer reproductive ecology. (We saw only one case of embryos being resorbed. Many of our collections were late term and we detected no evidence of abnormality or abortion). Ovulation rates are near the highest reported, which indicates adequate pre-ovulation nutrition (Verme 1965). Most ova are fertilized and implant to develop into fetuses; no more than 10% fail to do so. The fetuses develop normally and grow to full term. Fawns are apparently born alive, yet 50–70% of them are dead within 4 weeks of birth.

The summer fawn mortality pattern in the herd is much like Trainer's (1975) observations in the Steen's Mountain herd, and Papez's (1976) observations in the Ruby Butte herd. The North Kings herd, however, suffers higher post-natal losses and lower winter fawn losses than either herd. This is probably due to the mild winters typical of the west slope of the Sierra Nevada. The works of Verme (1963, 1965, 1967, 1969), Murphy and Coates (1966), Robinette (1973) and Dauphiné (1976) all point to late pregnancy nutrition of the female as an important factor in post-natal juvenile mortality. Smith and Le Count (1976) relate this nutrition to preceding seasonal rainfall. Trainer (1975) has found that the coyote, principal predator on most mule deer herds, is the immediate agent of death in over one-half of Steen's Mountain post natal fawn losses.

Very early in our investigation we speculated about the role of spring nutrition in North Kings fawn survival. The results of analysis reported here, plus what is known from other studies lead to an hypothesis on the decline of the North Kings deer herd.

Robinette and Gashwiler (1955), and Julander Robinette, and Jones (1961) cited the importance of summer range quality to mule deer reproduction many years ago. At that time most management agencies were focusing on winter range rehabilitation. In their original survey of California deer, Longhurst, Leo-

**TABLE 8. Comparison of Reproductive Potentials of Western Mule Deer Herds. Data Listed As Per Deer Examined.**

| Herd or area | Yearlings | | | | | Adults (2 year +) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | *Year* | *n* | *% Pregnant* | *Fetal Rate* | *% Fertility* | *n* | *% Pregnant* | *Fetal Rate* | *% Fertility* | *Source* |
| Sublett, Idaho | 1954–56 | 9 | – | 1.56 | – | 24 | – | 1.96 | – | Julander et al. (1961) |
| North Kings, CA. | 1971–1975 | 21 | 90 | 1.33 | 93 | 81 | 95 | 1.72 | 92 | this report |
| Utah herds | 1950–1953 | 128 | 84 | 1.11 | – | 435 | 94 | 1.69 | – | Robinette et al. (1955) |
| San Joaquin, CA | 1960 | 3 | – | 1.00 | – | 37 | – | 1.49 | 84 | Jordan (1967) |
| Bison Range, Mont. | 1953–1963 | 18 | – | 1.37 * | 95 | 66 | – | 1.74 * | 91 | Nellis (1968) |
| Middle Park, Colo. | 1969–1971 | – | – | – | – | 135 | 93 | 1.72 | 94 | Gill and Swope (1972) |
| Steen's Mtn., Oregon | 1968–1974 | – | – | – | – | – | – | 1.31 † | – | Trainer (1975) |
| Devil's Garden, Calif. and Ore. | 1946–1947 | – | – | – | – | 49 | 98 | 1.75 | – | Chattin (1948) |
| | 1975 | 6 | 83 | 1.00 | 85 | 61 | 100 | 1.80 | 93 | Salwasser (1976) |
| Northern Utah | 1948–1949 | 14 | 57 | .78 | – | 50 | 92 | 1.52 | – | Robinette and Gashwiler (1950) |
| Antimony, Utah | 1954–1956 | 8 | – | .62 | – | 19 | – | 1.42 | – | Julander et al. (1961) |
| Doyle, CA. | 1949–1951 | | | | | 178 | 85 | 1.23 † | – | Lassen et al. (1952) |
| Ruby Butte, Nev. | 1969–1972 | 11 | 45 | .72 | – | 43 | 95 | 1.72 | – | Papez (1976) |
| Railroad Flat, Calif. | 1970–1971 | 10 | 10 | – | – | 43 | – | 1.46 † | – | Browning et al. (1973) |

* per pregnant doe
† per all ages of does examined

pold, and Jones (1952) noted the importance of summer brushfields to Sierra herds. In his recent text Moen (1973) documents the high metabolic requirements of late term does, and especially lactating does for protein and energy. Murphy and Coates (1966) cite as the apparent cause of post partum death in fawns from does on reduced protein diets during pregnancy, starvation caused by insufficient milk production. Verme's work indicated fawns from does on poor diets during pregnancy tended to be smaller and weaker than those on good diets, and they suffered mortality in relation to their size at birth.

Mule deer are a mid-successional species (Leopold 1966). They are geared physiologically and reproductively to prosper in disturbed environments that are mid-way along their return to mature vegetation. In the Sierra, it is the brushfields on burned and cut over forest sites that provide nutritious herbs and young browses to deer during late pregnancy and the lactation and weaning period. These habitats were principally created during an era of uncontrolled wildfire, overgrazing by livestock and extensive logging on lower elevation pine forests. These disturbances were dramatically reduced through fire control, grazing management and better timber practices during the 1950's. During that time high deer numbers selectively browsed the most palatable plants.

We hypothesize that a general curtailment of disturbance on middle elevation migration and summer ranges has led to a decline in the nutritional quality of deer habitats during the last trimester of pregnancy and the lactation period. The consequence has been a reduction in fawn survival related principally to poor nutrition, but abetted by the concurrent losses of brushfield and other cover used by fawns for protection from weather and predation. The coyote may well be the principal agent of death for most fawns, but the impact of predation on the herd has been enhanced ultimately by the more basic ecological factors related to habitat quality. The range has just grown too old to support a productive deer herd.

It may seem inconsistent that a herd under poor nutrition could sustain such high reproduction potentials. Yet Verme (1965, 1969) documented a compensatory response of high ovulation in does on poor nutritional planes, that lost their fawns at birth and had the rest of the summer to regain vigor. Ransom (1968) and Dauphiné (1976) found similar compensatory responses in wild deer and caribou. It is thus not inconceivable that a herd can sustain high reproductive potentials on a range that prevents high fawn survival. Compensatory breeding may be the key to the ability of deer to "erupt" as range conditions improve.

One of the North Kings management goals is to reintroduce disturbance to forested habitats. In testing this hypothesis it will be important to monitor changes in the reproductive performance of the herd. The knowledge about age specific rates and variances cited in this report will allow an experimental design to be developed. As fawn survival increases in response to favorable forage and cover, fetal rates should fall slightly in mature age does. This would be the natural response of does to the added stress of nursing more fawns through the summer period. A higher incidence of twin survival would also lower the availability of milk to both fawns. Yearling fertility may also drop under range conditions leading to high fawn survival.

Management of mule deer ranges is expensive, and may require significant tradeoffs with other resource uses, such as timber and domestic livestock. It is imperative that research provide sound information to land managers on the

proper prescriptions. This can only come from well designed hypothesis testing. The work reported here proposes the hypothesis. It should be tested either on a comparison or before and after basis, before massive commitments of money and action are made.

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# SPRING-SUMMER PHYTOPLANKTON PRODUCTION IN HUMBOLDT BAY, CALIFORNIA [1]

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**Phytoplankton primary production was measured in Humboldt Bay, California, from May to September 1972. Chlorophyll-light and isotopic carbon methods were employed throughout the 4-month study. Overall mean chlorophyll *a* concentration was 4.10 mg/m$^3$, while the mean photosynthetic assimilation ratio was 11.07 g C/h/g Chl *a*. Mean primary production was 1.05 g C/m$^2$/day for lower low water, and 1.50 g C/m$^2$/day for higher high water. Total phytoplankton production was calculated from areal measurements, and ranged from 7.89 to 117.72 g C ($\times 10^6$)/day for lower low water, and from 22.86 to 122.72 g C ($\times 10^6$)/day for higher high water surface areas, respectively. Nutrient concentrations and light penetration apparently limited phytoplankton production at different times during the study. Photosynthetic pigment concentrations, assimilation ratios, and phytoplankton production in Humboldt Bay are of similar magnitude to values reported for the most productive marine areas such as upwelling regions, coastal embayments, and estuaries.**

## INTRODUCTION

Humboldt Bay is a shallow-water estuary on the northern California coast. Broad expanses of intertidal mudflats with extensive growth of aquatic macrophytes characterize the two major sections of the Bay, North and South bays (Keller 1963; Harding 1973). The fringes of the embayment support substantial salt marshes.

Freshwater input is somewhat limited and the influence of the neritic water mass on bay hydrography is marked. Tidal flushing is the dominant physical process affecting the estuary. Skeesick (1963) reported that approximately 44% of the mean higher high tide volume of the Bay is expelled during the normal sequence of tides from higher high to lower low water.

Sources of nutrient input include the tidal influx of upwelled waters, seasonal freshwater input from several small rivers and sloughs, salt marsh runoff, and regenerated nutrients mixed into the water column from the mudflats. Recorded nutrient levels are limited to a series of phosphate concentration measurements conducted by Skeesick (1963). The quantities measured resemble values for rich, upwelled waters.

The waters of Humboldt Bay are well-mixed as extensive tidal flushing, seasonal lack of freshwater influence, and wind-driven mixing prevent significant stratification. Gast (1962) found no vertical gradient in a temporal series of salinity measurements. Skeesick (1963) noted seasonal horizontal gradients in salinity, but concluded that spring and summer gradients were nonexistent. Detailed descriptions of water circulation and hydrographic properties may be found in Gast (1962), Skeesick (1963), and Gast and Skeesick (1964).

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Phytoplankton production has been measured in numerous estuaries similar to Humboldt Bay (Pomeroy 1959; Stross and Stottlemeyer 1965; Williams 1966; Taylor and Hughes 1967). Autotrophic production in such shallow estuaries often exceeds that of rich neritic water masses, and supports certain important marine fisheries. Estuarine areas are the most affected by man's activities; in the case of Humboldt Bay, water quality is affected by dredging, domestic and industrial effluents, thermal and radionuclide inputs, and ship traffic. Although these perturbations may already have affected production in the Bay, the measurements we report here will serve as a reference point for future alterations of this environment.

## MATERIALS AND METHODS

Eighteen stations were selected in Humboldt Bay based on earlier studies of water quality, circulation, and preliminary production determinations (Gast 1962; Skeesick 1963; Gast and Skeesick 1964; Faulkner and Mason 1972). Each station was assigned a number, with designations based on position relative to geographical landmarks and navigational aids (Figure 1). The 4-month sampling period extended from May to September 1972, covering most of the productive season.

Phytoplankton production measurements were made according to the chlorophyll-light method of Ryther and Yentsch (1957). Incident radiation was measured with a recording pyranometer located at Pacific Gas and Electric Company's Humboldt Bay Power Plant. Pyranometer traces were integrated by planimetry. Light penetration was measured by a Secchi disc calibrated with a submarine photometer. The relative photosynthetic rate was calculated according to a modification of the method of Ryther and Yentsch (1957) and Ryther (1956).

Surface water samples were collected by submerging a 2-liter (2.3-qt) opaque container in an inverted position and rotating it underwater to fill. Replicate 0.5-liter (0.4-qt) aliquots were filtered through HA Millipore membrane filters with 0.8-$\mu$m pore size and a 47-mm (1.9-inch) diameter. The filters were stored in desiccators with silica gel at $-10$ C (14 F) in the dark prior to pigment analysis.

Chlorophyll concentrations were determined by the method of Creitz and Richards (1955) as modified from Richards and Thompson (1952) and discussed in Strickland and Parsons (1968).

Photosynthetic rate measurements were made for eight stations (Stations 4, 6, 8, 10, 12, 14, 16 and 18) by the carbon-14 isotope technique (Steeman Nielsen 1952). Water samples were collected from the surface and incubated with 5 $\mu$ Ci C-14 bicarbonate in 125 ml light and dark bottles for 4 hr. at the ambient seawater temperature using natural illumination. Incident radiation was recorded with a pyranometer. After incubation, the samples were filtered through HA Millipore membrane filters with 0.45-$\mu$m pore size and a 25-mm (1-inch) diameter under moderate vacuum pressure (350–500 mm Hg). Activity was determined with a Packard Model 2111 Liquid Scintillation Counter using Bray's solution.

Carbonate alkalinity was calculated from pH and salinity data taken during the incubation period. A Beckman expanded scale pH-meter and hydrometer were used, respectively, and the carbonate alkalinity, total alkalinity, and total carbon

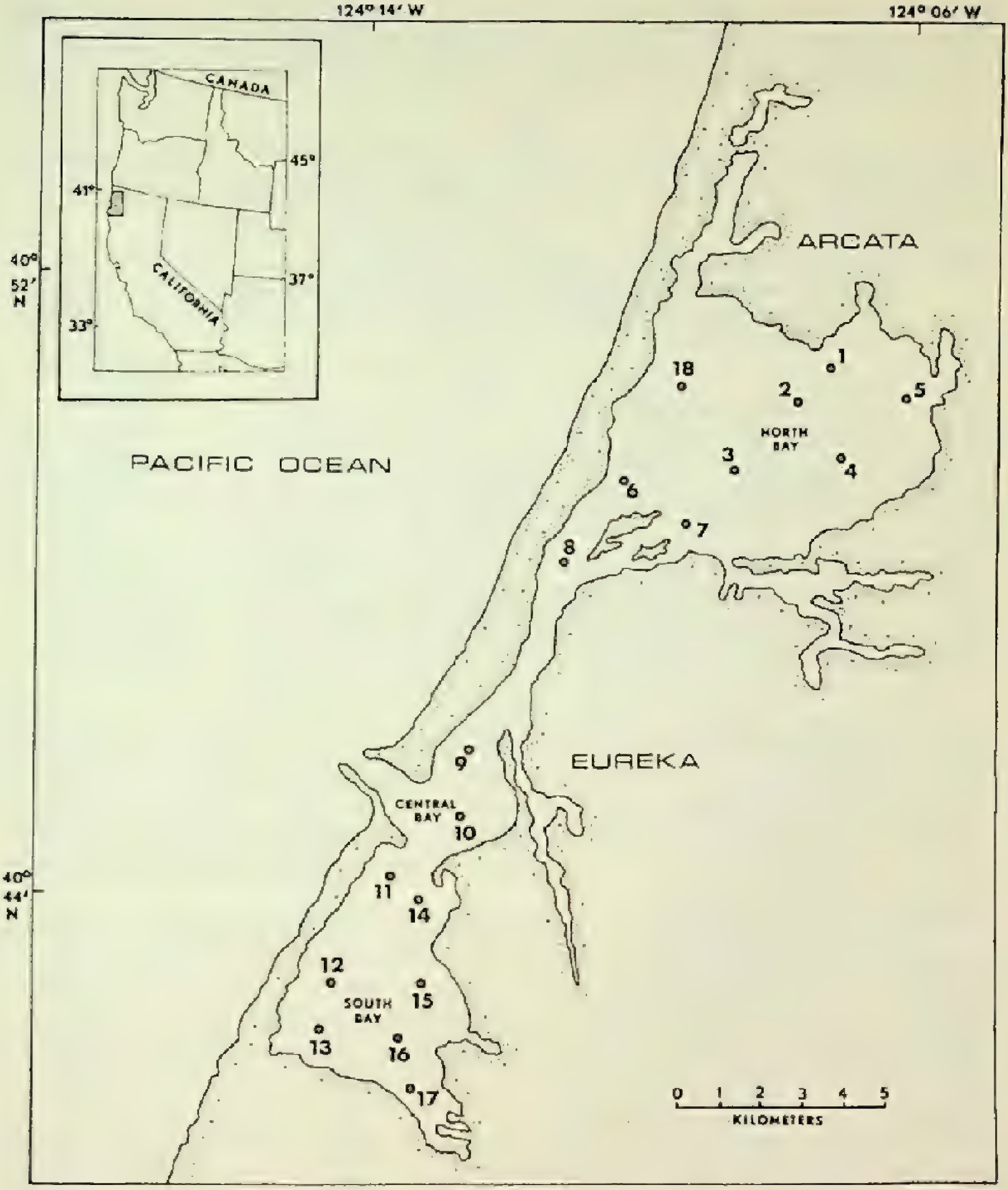


FIGURE 1. Humboldt Bay and environs showing locations of stations (1–18) where primary production was measured.

dioxide were calculated according to the methods of Strickland and Parsons (1968).

Productivity values obtained were subsequently correlated with chlorophyll *a* concentrations at each station and the assimilation coefficients were calculated (Ryther 1956, Ryther and Yentsch 1957, Curl and Small 1965). The total area of the bay and the areas of individual sections corresponding to the selected stations were determined using planimetry and the Coast and Geodetic Survey Chart No. 5832 of Humboldt Bay for both mean lower low and mean higher high

water. Total phytoplankton production in Humboldt Bay was calculated from production determinations made with the chlorophyll-light method for individual bay sections and area measurements for those sections.

## RESULTS

Chlorophyll *a* concentrations ranged from 0.09 mg/m³ on 10 August at Station 11 to 44.8 mg/m³ on 18 June at Station 5. Mean concentrations ranged from 1.16 to 7.44 mg/m³ (Table 1).

**TABLE 1. Incident Solar Radiation, Relative Phytosynthesis, Extinction Coefficient, Chlorophyll *a*, Assimilation Ratio, and Phytoplankton Photosynthesis Data.** Values are Expressed as Means With Standard Errors Where Appropriate. Sample Sizes Are Indicated in Parentheses.

| Date | Incident solar radiation ($g$ Cal/cm²/day) | R (Ryther & Yentsch 1957) | Extinction coefficient (/m) | Chl *a* (mg/m³) | Assimilation ratio (g C/h/gChl *a*) | Phytoplankton photosynthetic rate (mg C/m³/h) |
|---|---|---|---|---|---|---|
| 27 April.... | 298 | 17.2 | 1.74 ± 0.10 (18) | 5.37 ± 0.53 (18) | 2.50 ± 0.82 (4) | 13.48 ± 2.18 (4) |
| 17 May.... | 635 | 25.6 | 1.79 ± 0.11 (18) | 7.44 ± 0.91 (18) | 11.83 ± 3.47 (7) | 54.78 ± 18.73 (7) |
| 14 June.... | 595 | 25.0 | 2.30 ± 0.29 (18) | 4.36 ± 0.58 (18) | 4.73 ± 0.85 (8) | 16.24 ± 3.10 (8) |
| 18 June.... | 720 | 27.0 | 1.34 ± 0.09 (18) | 4.77 ± 1.72 (18) | 4.73 ± 0.85 (8) | 16.24 ± 3.10 (8) |
| 4 July...... | 630 | 25.4 | 1.19 ± 0.04 (18) | 3.39 ± 0.57 (18) | 20.96 ± 5.14 (4) | 48.57 ± 6.34 (4) |
| 12 July...... | 438 | 20.6 | 1.68 ± 0.11 (18) | 1.16 ± 0.80 (18) | 16.27 ± 4.53 (8) | 37.37 ± 4.88 (8) |
| 25 July...... | 298 | 17.2 | 1.29 ± 0.12 (18) | 1.45 ± 0.18 (18) | 10.95 ± 4.87 (7) | 49.96 ± 21.21 (7) |
| 10 August | 736 | 27.4 | 1.22 ± 0.13 (18) | 3.02 ± 0.41 (18) | 17.59 ± 6.98 (7) | 24.48 ± 7.06 (7) |
| 23 August | 480 | 22.2 | 1.11 ± 0.11 (18) | 2.70 ± 0.39 (18) | 8.54 ± 2.20 (8) | 16.16 ± 2.80 (8) |
| 7 Sept.... | 438 | 20.6 | 0.95 ± 0.11 (18) | 2.62 ± 0.52 (18) | 7.78 ± 2.19 (8) | 24.82 ± 2.88 (8) |

Light extinction coefficients (k) ranged from 0.38/m on 23 August at Stations 9 and 11, and 7 September at Station 9, to 6.19/m for 14 June at Station 5. Mean k values ranged from 0.95/m to 2.30/m (Table 1).

The measurement of daily surface radiation, accompanied by extinction coefficient values enabled the calculation of R, the relative phytosynthetic rate (Ryther and Yentsch (1957)).

Assimilation ratios in the study area ranged from 1.28 gC/hgChl *a* on 17 May at Station 6, to 61.67 gC/h/gChl *a* on 12 July at Station 8. The mean of all values was 11.07 ± 1.50 (standard error) gC/h/gChl *a*. While several measurements yielded values in the neighborhood of 3.7 gC/h/gChl *a*, the figure presented by Ryther and Yentsch (1957), the mean assimilation ratio for Humboldt Bay was nearly three times higher, closer to the value discussed by Curl and Small (1965) as applicable to nutrient-rich waters.

Phytoplankton production values measured by the C-14 technique ranged from 1.84 mgC/m³/h on 23 August at Station 10, to 183.16 mgC/m³/h on 25 July at Station 8. Mean productivity values were calculated for each sample day and for individual stations over the entire 4-month sampling interval. Daily means ranged from 13.48 mgC/m³/h on 27 April to 54.78 mgC/m³/h on 17 May. Mean values for the eight stations ranged from 21.36 mgC/m³/h at Station 12, to 42.46 mgC/m³/h at Station 8.

Production measurements with the chlorophyll-light method provided values for total phytoplankton production in a given section of Humboldt Bay. The surface area of each station was calculated for mean lower low water and for mean higher high water. Total phytoplankton production in the Bay was determined by measuring the production rate per unit surface area at the 18 stations (Equation 1), and calculating the product of those values and the estimated

surface area per station (Equation 2). The sum of production values for each station resulted in an estimate of total phytoplankton production in Humboldt Bay (Equation 3).

$$P = R/k \times \text{Chl } a \times \text{A. R.} \tag{1}$$

where $P$ = primary production ($gC/m^2/day$)
$R$ = relative photosynthesis
$k$ = extinction coefficient ($/m$)
and A. R. = assimilation ratio ($gC/h/gChl\ a$)

$$P\ (gC/m^2/day) \times (m^2/section) = gC/section/day \tag{2}$$

$$\Sigma\ gC/section/day = gC/Humboldt\ Bay/day \tag{3}$$

Williams (1966) weighted the surface area-production products by dividing the sum of those values by the total area of the estuary under study. Humboldt Bay production data were treated according to this method. Mean production values were also calculated for individual sampling dates and an overall mean for the 4-month interval was determined.

Production rates determined by the chlorophyll-light method (Equation 1) ranged from 0.02 $gC/m^2/day$ for Station 15 on 7 September to 9.38 $gC/m^2/day$ for Station 10 on 17 May, with an overall mean of 0.82 $gC/m^2/day$. Mean production values were calculated for individual sampling dates and ranged from 0.35 $gC/m^2/day$ on 14–16 June to 8.84 $gC/m^2/day$ on 17 May.

Values obtained by weighting production rates with section areas ranged from 0.26 $gC/m^2/day$ on 25 July to 3.90 $gC/m^2/day$ on 17 May for lower low water section areas, and from 0.35 $gC/m^2/day$ on 14–16 June to 1.87 $gC/m^2/day$ on 17 May for higher high water section areas. The weighted means were 1.05 $gC/m^2/day$ for lower low water and 1.50 $gC/m^2/day$ for higher high water areas over the entire sampling period (Table 2).

**TABLE 2. Total and Weighted Phytoplankton Production Values for Mean Lower Low Water and Mean Higher High Water Surface Areas in Humboldt Bay.**

| *Date* | $P_{total}$ *($gC \times 10^6/day$) Low water* | $P_{total}$ *($gC \times 10^6/day$) High water* | *Weighted production ($gC/m^2/day$) Low water* | *Weighted production ($gC/m^2/day$) High water* |
|---|---|---|---|---|
| 27 April | 19.77 | 31.09 | 0.65 | 0.47 |
| 17 May | 117.86 | 122.72 | 3.90 | 1.87 |
| 14 June | 10.71 | 22.86 | 0.35 | 0.35 |
| 18 June | 16.98 | 45.01 | 0.56 | 0.69 |
| 4 July | 33.38 | 75.14 | 1.10 | 1.15 |
| 12 July | 19.46 | 49.01 | 0.64 | 0.75 |
| 25 July | 7.89 | 27.75 | 0.26 | 0.42 |
| 10 August | 39.28 | 86.34 | 1.30 | 1.32 |
| 23 August | 13.74 | 34.10 | 0.45 | 0.52 |
| 7 Sept. | 17.77 | 30.67 | 0.59 | 0.47 |

Total phytoplankton production in Humboldt Bay was calculated according to the modified chlorophyll-light method (Equations 2 and 3) for both lower low and higher high water surface areas. Production values for the entire bay ranged from $7.89 \times 10^6$ gC/day on 25 July to $117.86 \times 10^6$ gC/day on 17 May for lower low water, and from $22.86 \times 10^6$ gC/day on 14–16 June to $122.72 \times 10^6$ gC/day on 17 May for higher high water.

## DISCUSSION

The chlorophyll *a* concentrations measured in Humboldt Bay are similar to values obtained for nutrient-rich estuarine waters (e.g. Stross and Stottlemeyer 1965). No horizontal gradient in chlorophyll *a* concentrations was apparent in Humboldt Bay. The extensive neritic influence, tidal flushing, and complete horizontal and vertical mixing apparently prevented the development of between-station differences in pigment composition.

The mean assimilation ratio for Humboldt Bay was 11.07 gC/h/gChl *a*. This value corresponds to photosynthetic ratios obtained for productive areas with high nutrient concentrations (Holmes 1958; Anderson 1964; Curl and Small 1965).

Assimilation ratios reflected total production results for May and June (Tables 1 and 2). The high phytoplankton production in mid-May corresponded to a large carbon-chlorophyll ratio, indicating favorable nutrient conditions. Ratios calculated for mid-June were less than half the mean for the entire sampling period, possibly reflecting nutrient limitation. These lower ratios, however, have about the same value as ratios reported for areas where nutrients are known to be non-limiting (Burkholder and Mandelli 1965; Thomas 1970).

Phytoplankton photosynthetic rates measured by the isotopic carbon method were comparable to those reported for other highly productive estuarine areas. There was no apparent gradient in phytoplankton photosynthetic rates determined on a per unit volume basis for Humboldt Bay. Previous studies of estuarine primary production (Stross and Stottlemeyer 1965; Williams 1966; Taylor and Hughes 1967) measured significant differences in the photosynthetic rates for upstream and downstream stations. Freshwater input in Humboldt Bay is confined to bay extremes as in the Patuxent River, Chesapeake Bay, and North Carolina estuaries. However, virtually no horizontal or vertical stratification occurs during the late spring and summer months in the Bay as a consequence of extensive tidal flushing and comparatively small freshwater influence (Gast 1962; Skeesick 1963; Gast and Skeesick 1964). These seasonal hydrographic and circulation characteristics of Humboldt Bay were probably responsible for the homogeneity of the phytoplankton population as measured by the distribution of chlorophyll content and photosynthetic rates.

Variations in high and low tide phytoplankton production were not as great early in the season (Table 2). May and June values indicate the importance of Central Bay stations to total Bay production in that surface areas for those stations are subject to less fluctuation per tidal cycle. July, August, and September production values varied markedly with tidal height, indicative of increased photosynthetic activity over the mudflats caused by increased light penetration and incident radiation (Table 1). Total production in the Bay is greatly affected by enhanced production at high water in the intertidal mudflat areas during these months.

The primary production of Humboldt Bay is similar to that of highly productive aquatic ecosystems which have been studied. While it is impossible to evaluate conclusively the health of this estuarine system on the basis of primary production measurements alone, the magnitude of photosynthetic carbon fixation measured indicates that unique and substantial changes have not occurred yet. Additional measurements of primary production in Humboldt Bay may be

compared to the results reported here, and changes in this essential feature of the estuarine ecosystem can be assessed.

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# NOTES

## FIRST OREGON RECORDS FOR TWO BLENNIOID FISHES

Two species of northern blennioid fishes are herein recorded for the first time as occurring in the intertidal zone along the coast of Oregon. On July 20, 1955, C. E. Bond and J. M. Bali collected two specimens identified by Bond as *Cebidichthys violaceus* from a high intertidal pool between Harris Beach State Park and the city of Brookings (Lat. 42°4'N, Long. 124°17'W). These specimens, measuring 129 and 118 mm (5.1 and 4.6 inches) SL, have been recently deposited in the fish collection of the Department of Fisheries and Wildlife, Oregon State University (catalogue no. 5121). This collection extends the range of *C. violaceus* into Oregon waters 22 km (13 miles) north of Crescent City, California which was noted by Miller and Lea (1972) to be the northern limit of this species.

On April 15, 1972, two specimens of *Anoplarchus insignis* were collected in a low intertidal pool at Yaquina Head, Oregon (Lat. 44°40'N, Long. 124°5'W). A third individual was collected at the same locality on May 5, 1973. These three pricklebacks, originally identified as *Anoplarchus purpurescens,* were later found to agree with Peden's (1966) diagnosis of *A. insignis* by having a comparatively narrower isthmus and greater dorsal, anal, and vertebral counts than *A. purpurescens.* The fishes collected in 1972 measured 78 and 41 mm (3.1 and 1.6 inches) SL with isthmus widths of 1.3 and 1.9% of the standard length, respectively. The individual collected in 1973 measured 50 mm (2.0 inches) SL with an isthmus width of 1.3%. X-ray analysis revealed 60 dorsal spines, 44 anal rays, and 65 vertebrae in all three individuals. These fishes also were deposited in the OSU fish collection (catalogue numbers 5122, 5123). Peden (1966) noted that *Anoplarchus insignis* ranges from Attu Island to Puget Sound and the Strait of Juan de Fuca. These Oregon collections extend its range 255 km (153 miles) to the south.

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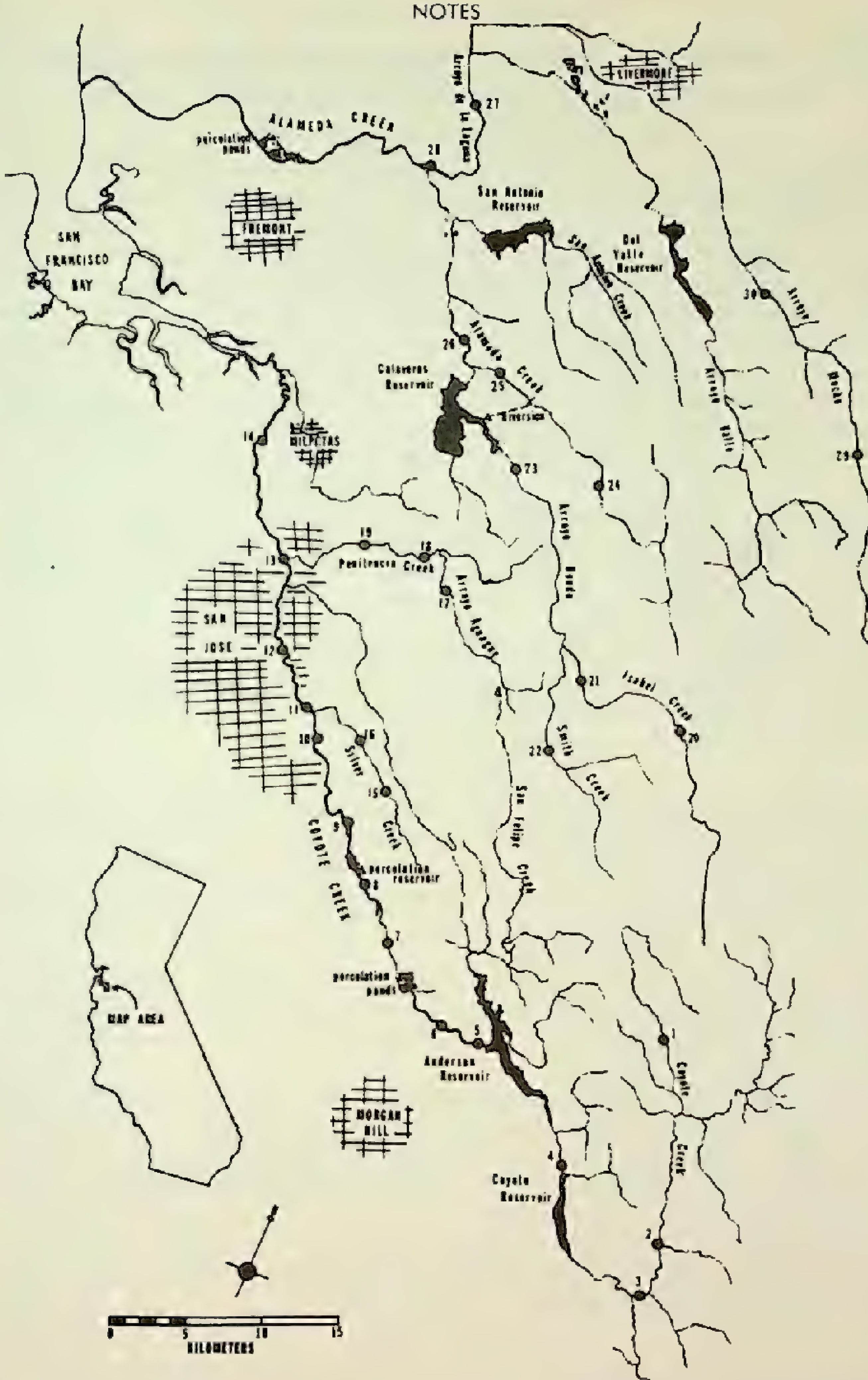


Figure 1. Location of 1972–1977 collection stations on Alameda and Coyote creeks. Site numbers are the same as those used in Table 1.

# ADDITIONAL RECORDS ON THE DISTRIBUTION AND STATUS OF NATIVE FISHES IN ALAMEDA AND COYOTE CREEKS, CALIFORNIA

In a recent paper, Aceituno et al. (1976) summarized the known fish distribution records for Alameda and Coyote creeks and assessed the present status of both native and nonnative species. For Alameda Creek they concluded: 1) as many as 4 of the 12 original species were possibly no longer present; 2) riffle sculpins, *Cottus gulosus,* and California roach, *Hesperoleucus symmetricus,* although not collected by them, may still persist in headwater areas; 3) tule perch, *Hysterocarpus traski,* although not present in sections they sampled, are probably present in percolation ponds in the lower part of the river; and 4) rainbow trout, *Salmo gairdneri,* may have become reestablished from runs of steelhead in lower Alameda Creek. For Coyote Creek they concluded: 1) Pacific lamprey, *Entosphenus tridentatus,* Western brook lamprey, *Lampetra richardsoni;* thicktail chub, *Gila crassicauda;* splittail, *Pogonichthys macrolepidotus;* speckled dace, *Rhinichthys osculus;* tule perch; and Sacramento perch, *Archoplites interruptus,* have not recently been collected and are probably no longer present; 2) California roach, riffle sculpin, and Sacramento squawfish, *Ptychocheilus grandis,* were no longer present below Anderson Reservoir, but might be present in upper Coyote Creek.

Between 1972 and 1977 we sampled numerous locations in both river basins using seines and electroshockers (Figure 1). Our results, summarized in Table 1, and other unpublished records with which we are familiar, modify or clarify their conclusions for the following native species:

## ALAMEDA CREEK

*Rainbow Trout.* Reestablishment of rainbow trout in the middle reaches of Alameda Creek by spawning steelhead is prevented or at least severely restricted by two inflatable (seasonal) dams and an 8-ft inclined drop structure in the channelized section of the creek near the percolation ponds. Rainbow trout are still present and abundant at sites on Isabel, Smith, Arroyo Hondo, Arroyo Mocho, and upper Alameda creeks.

*California Roach.* As suggested by Aceituno et al. (1976), California roach are present in tributary streams. In fact, we found them to be still widespread and abundant, being found at six of eight tributary sites and also at three sites in upper Alameda Creek.

*Riffle Sculpin.* We thoroughly sampled sites with cool, permanent water on Isabel, Smith, Arroyo Hondo, Alameda, and Arroyo Mocho creeks without encountering riffle sculpin. We collected prickly sculpin (*Cottus asper*) in Arroyo Hondo Creek. The only record for riffle sculpin within the basin remains the collection in 1938 by Shapovalov.

*Speckled Dace.* Not mentioned by Aceituno et al. (1976), speckled dace were reported by Snyder (1905) for Isabel and Arroyo Hondo creeks. In our recent sampling on those streams we found none.

## COYOTE CREEK

*Pacific Lamprey.* Although we did not collect bottom samples usually necessary to locate lamprey ammocoetes, we recently encountered them at one site in lower Coyote Creek. It seems likely that they are more widespread.

**Table 1. Distribution and Abundances of Fishes in Coyote Creek and Alameda Creek Drainages, from Collections Made from 1972 to 1977.**

| | *Entosphenus tridentatus* | *Salmo gairdneri* | *Hesperoleucus symmetricus* | *Lavinia exilicauda* | *Orthodon microlepidotus* | *Ptychocheilus grandis* | *Rhinichthys osculus* | *Catostomus occidentalis* | *Gasterosteus aculeatus* | *Archoplites interruptus* | *Cottus asper* | *Cottus gulosus* | *Carassius auratus* | *Cyprinus carpio* | *Gambusia affinis* | *Lepomis cyanellus* | *Lepomis macrochirus* | *Micropterus salmoides* | *Pomoxis nigromaculatus* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| COYOTE CREEK DRAINAGE[1] | | | | | | | | | | | | | | | | | | | |
| *Coyote Creek* | | | | | | | | | | | | | | | | | | | |
| 1—Middle Fork, Coe State Park | | 2 | 3 | | | 1 | | 2 | | | | 2 | | | | | | | |
| 2—Gilroy Hot Springs | | | 3 | | | | | 1 | | | | | | | | | | | |
| 3—2 km downstream from site 2 | | | 5 | | | 1 | | | | | | | | | | | | | |
| 4—Below Coyote Reservoir | | | | X | | X | | X | | | | | | | | | | | X |
| 5—Below Anderson Reservoir | | | 1 | 2 | | | | 3 | | | | | | | 2 | | 2 | | |
| 6—Above percolation ponds, 2 km below Anderson Reservoir | | | 1 | 2 | | | | 3 | 4 | | | | | | | | | | |
| 7—Riverside Golf Course Road | | | 3 | 2 | 1 | | | 2 | 4 | | X | | 2 | | 3 | 1 | 1 | 1 | |
| 8—Upstream from Metcalf Road | | | | 3 | | | | 4 | 2 | | 4 | | | | | | | | |
| 9—Tennant Road | | | | 4 | 1 | | | 2 | 3 | | | | | | 2 | | | | |
| 10—Above and below Hellyer Park | | | | 3 | | | | | | | | | | | 1 | 1 | 1 | 1 | |
| 11—Singleton Road | | | | 1 | | | | | | | | | | | 1 | 1 | | | |
| 12—Happy Hollow City Park | | | | | | | | | | | | | | | 1 | | | | |
| 13—Mouth of Penitencia Creek | | | 3 | 3 | | | | 2 | 3 | | | | | | 4 | 1 | | | |
| 14—Highway 237 | X | | | 3 | | | 1 | | | | | | 5 | | 4 | 1 | | | |
| *Silver Creek* | | | | | | | | | | | | | | | | | | | |
| 15—Upper Silver Creek Road | | | 3 | | | | | | | | | | | | | | | | |
| 16—Near Capitol Expressway | | | | | | | | | 3 | | | | | | | | | | |
| *Arroyo Aguague* | | | | | | | | | | | | | | | | | | | |
| 17—1 km upstream from mouth | | 3 | | | | | | | | | | | | | | | | | |
| *Penitencia Creek* | | | | | | | | | | | | | | | | | | | |
| 18—Alum Rock Park | | 1 | 3 | | | | | | | | | 2 | | | | | | | |
| 19—1 to 3 km downstream from park | | | 4 | | | | | | | | | | | | | 1 | | | |
| ALAMEDA CREEK DRAINAGE | | | | | | | | | | | | | | | | | | | |
| *Isabel Creek* | | | | | | | | | | | | | | | | | | | |
| 20—Bayou Road | | | | | | | | | | | | | | | | | | | |
| 21—Kincaid Road | | 4 | 2 | | | | | 1 | | | | | | | | | | | |
| *Smith Creek* | | | | | | | | | | | | | | | | | | | |
| 22—Mt. Hamilton Road | | 2 | 3 | | | | | 2 | | | | | | | | | | | |
| *Arroyo Hondo* | | | | | | | | | | | | | | | | | | | |
| 23—Arroyo Hondo Road | | 5 | 2 | | | | | 3 | | | 3 | | | | | | | | |
| *Alameda Creek* | | | | | | | | | | | | | | | | | | | |
| 24—Mile Post 5, Ohlone Camp Road | | 2 | 3 | | | | | | | | | | | | | | | | |

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 25—0.5 km upstream from junction with Calaveras Creek ...... | 2 | 3 | | | | | 1 | | | | | | | | 3 |
| 26—Sunol Park Headquarters .................... | | 5 | | | 3 | | | | | | | | | | 1 |
| *Arroyo de la Laguna* | | | | | | | | | | | | | | | |
| 27—Castlewood Road .... | | | | | | | 3 | | 1 | | | 2 | 2 | | |
| 28—Near mouth............ | | 1 | | | | | 3 | | | 2 | | | | | |
| *Arroyo Mocho* | | | | | | | | | | | | | | | |
| 29—Lawrence Laboratory pumping station | 4 | 2 | | | | | 2 | | | | | | | | 1 |
| 30—1 km above Del Valle Road............... | 2 | 4 | | | | | | | | | | | | | 3 |

[1] Abundances are rated 1–5, where 1 indicates rare and 5 indicates very abundant; X indicates presence, but abundance not estimated.

*California Roach.* As predicted by Aceituno et al. (1976), California roach are present in upper Coyote Creek. We collected them at three sites in upstream Coyote Creek and in two tributaries, Silver and Penitencia creeks. In addition, we collected them (often in abundance) at four sites below Anderson Reservoir, where their distribution is complimentary to that of hitch (*Lavinia exilicauda*); California roach were more abundant in the shallower portions of the creek, while the hitch preferred areas with extensive, deep pools. A similar complimentary distribution of roach and hitch based upon depth was reported for the nearby Pajaro River system by Avise, Smith, and Ayala (1975).

*Sacramento Squawfish.* We did not collect squawfish downstream from Anderson Reservoir, and the last records of which we are aware are from two sites in the downtown San Jose area for 1960 (L. J. Hendricks, San Jose State Univ., pers. commun.). We did, however, collect the species upstream and downstream from Coyote Reservoir. They are also probably present in both Anderson and Coyote reservoirs. In upper Coyote Creek, they were found to be common by Guzzetta (1974), in his extensive survey of the fishes of Henry Coe State Park.

*Speckled Dace.* We collected a single specimen from lower Coyote Creek and R. L. Hassur (San Jose State Univ., pers. commun.) collected specimens near the Riverside Golf Course in 1974. The latter site is intermittent, but downstream from permanent, extensive percolation ponds and their associated channels. The species is apparently still present, although rare, at two sites.

*Riffle Sculpin.* We collected riffle sculpin in the headwaters of Coyote Creek and in Penitencia Creek, a tributary to lower Coyote Creek. They are common at both locations. In his study of the fishes of Henry Coe State Park, Guzzetta (1974) erroneously assigned the sculpin to *Cottus aleuticus.*

With our additional records, Alameda Creek drainage appears to have lost only riffle sculpin and speckled dace out of 13 native species. Coyote Creek has lost 5 of 16 native species (Western brook lamprey, thicktail chub, splittail, tule perch, and Sacramento perch). In addition, speckled dace are very rare, riffle sculpin are confined to upper Coyote Creek and Penitencia Creek, and Sacramento squawfish are present only above Anderson Reservoir. Four of the five species lost from Coyote Creek are species usually associated with deeper, slower parts of streams. Coyote Creek is presently managed for groundwater percolation, and the lower portions of the stream which previously offered potential habitat now suffer from greatly reduced flows and associated water quality problems.

These losses of native fishes have not been accompanied by widespread establishment of nonnative species. We collected a total of seven exotic species in the two basins (Table 1), but most of these collections were of few and scattered individuals. We found only mosquitofish (*Gambusia affinis*), in Coyote Creek, and goldfish (*Carassius auratus*) and green sunfish (*Lepomis cyanellus*), in both basins, to be well established.

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# BOOK REVIEWS

## Murex Shells of the World: An Illustrated Guide to the Muricidae

By George E. Radwin and Anthony D'Attilio. Stanford University Press, Stanford, Calif., 1976; 284 p., 32 color plates, 192 text figures. $35.00.

Historically, the pectens, spondylids, cones, cowries, harps, volutes, olives and muricids have been the "butterflies" of the molluscan world—prized among collectors for their beauty of color and form. At every turning one has treatises, picture books and masses of information concerning cowries, harps, volutes and cones, but nearly a century has gone by since the muricids have received comprehensive treatment such a offered in this volume.

In the 14 pages of introduction, the authors briefly discuss classification of the family, significant anatomical features, feeding methods and cues, shell formation, habits and distribution, and the fossil record. This is followed by a 4-page outline (listing) of the taxonomic assignments the authors have made in their 198 pages of species accounts. Sixteen species are described as new in an Appendix, and this is followed by an illustrated glossary, a listing of sources for the figures, a bibliography, and an index.

It was of interest to me that only two of the scientific combinations (generic and specific names) that I learned in college for the 20 California species included in this volume are still valid. By not having kept up-to-date with muricid taxonomy, I failed even to associate several taxa with common species I have known all my life.

The authors were greatly impressed with using the radula as a guide to muricid classification, so some of their allocations (or failures to include) were a bit startling. Malacologists seem generally pleased with the work, but several I have talked to have been unhappy over omissions, i.e., they would have liked broader coverage as would have been logical had not radular structure dictated otherwise. A criticism that I felt has merit if true, is that important material in several non-institutional collections was ignored even though it was available for study. If an examination of such material would have resulted in modification of the taxonomic treatment, such criticism would be justified.

One cannot fault the illustrations, however. The color photography by David K. Mulliner is superb, and the abundant text figures furnish close-up details of sculpture, radular teeth, apical whorls, and other features important in muricid taxonomy. Not only is the book worthy of an honored place on the malacologist's and shell collector's reference shelf, it would not shame the bibliophile who displays it on his or her living room coffee table.—*John E. Fitch.*

## In the Ring of the Rise

By Vincent C. Marinaro. Crown Publishers, Inc., New York, N. Y. 1976; 184 p., illustrated. $12.95.

There are many, many new fishing books being published today. Few of them, in my opinion, have too much to offer the serious fisherman/reader. Marinaro's, *In the Ring of the Rise,* is of comparable quality to his first book, *A Modern Dry Fly Code,* which was hailed 25 years ago as "the first original American contribution to fly fishing".

Once again the scene is his highly productive, Pennsylvania limestone streams—big fish and light tackle. Marinaro has spent countless hours closely observing and photographing the feeding behavior of large brown trout. Various rise forms, from the most simple to the most complex are illustrated in a series of tremendous photographs. The photographs are exceptional, as is the text. The photos are discussed, explanations offered for the behavior of the fish, and all this is related to how the fisherman can improve his success. There is a strong chapter on the vision of the fish—what he perceives and how he perceives it. This highly complex discussion is again based on exhaustive observation, coupled with several experiments and photographs of the experiments.

Although the text discusses eastern waters (with the exception of a chapter on the Au Sable), there is much information for the western fly fisherman. Several of the last chapters have appeared as articles in various outdoor magazines, but they have been expanded, and are worth rereading anyway. This is a book that should make you think about what you are doing and why you are doing it when you're on the stream. I think you will also spend a great deal more time observing fish in slow, clear water situations and less time flogging the water.—*K. A. Hashagen Jr.*

**Fishes of the World**

by Joseph S. Nelson; John Wiley and Sons, New York, 1976; xiii + 416 p., illustrated.

According to the author, "One purpose dominated in the writing of this book—to provide a modern introductory systematic treatment of all major fish groups." Toward this end, he has presented a brief account of each of the various fish groups down to the level of family. for families, for instance, a common name, if available, is presented and the preferred zoogeographical habitat of the family members is mentioned. An outline drawing of a typical, if there be such a creature, family member usually is given, along with a few salient, though rarely diagnostic, characters. Maximum or average sizes may be mentioned, and genera and species belonging to the family are enumerated. Some, but not all, genera are listed. If an important revisionary or similar work is known to the author, he usually has listed it.

The volume contains a wealth of information, but the latest references are dated 1973. I'd like to have seen a bit more space between family accounts so that I could annotate my copy as pertinent literature is published. I'd also liked to have seen a listing of all genera within a family where there are fewer than 10. As it is, a family containing seven genera might have all listed or only three or four, etc.

In his introductory chapter, the author estimates that there are 18,818 living species of fish in the world, and these belong to 4,032 genera in 450 families. In a 14-page appendix, he lists the 450 families in their respective classes, orders, and suborders. A second appendix contains 45 fish distribution maps, 40 of which pertain to specific families. The bibliography, through 1973, is excellent, and the volume is well-indexed. It is the type of reference that should be kept within easy reach on bookshelf or desk, as it will be referred to often by those who invest in a copy.—*John E. Fitch.*

**WATERFOWL OF NORTH AMERICA**

by Paul A. Johnsgard; Indiana University Press, Bloomington & London, 1975; 575 pp., 104 black and white photos, 32 color photos, 63 drawings, 46 maps. $25.00

Dr. Johnsgard has successfully developed a volume that should prove useful to the greatest number of people. Without seriously overlapping the great works of Bent, Kortright or Delacour, the author has compiled up-to-date series accounts dealing with reproductive biology, identification, and ecology of every waterfowl species presently known to breed on the North American continent. Emphasis is on possible application in conservation and management of each species.

The all new photographs and anatomically correct drawings by Dr. Johnsgard are excellent. Included are rare and questionable records, such as the Smew, Tufted duck, Bahama Pintail, Garganey, Baikal Teal, Falcated Duck and others. The twenty five pages of sources of information at the back of the book are particularly useful for further studies.

*Waterfowl of North America* is understandable to the nonprofessional, but still retains sufficient specific information to make it a useful reference for students and professional wildlife biologist. Ornithologists, bird lovers, waterfowl hunters and decoy carvers will also appreciate this new book.—*W. F. "Bill" Hart.*

**Advanced Bass Fishing**

by John Weiss; E. P. Dutton and Co., New York. 1976. XXViii + 256 p. Illustrated. $11.95.

As the title would indicate, *Advanced Bass Fishing* is not a book the beginning black bass angler could readily digest. Mr. Weiss begins with an introduction to the various species of black bass and how each relates to his environment. From there the author goes into factors affecting bass behavior such as lake structure, light penetration, oxygen content in the water, and water temperatures.

The largemouth species, being the most sought after, receives the lion's share of attention with separate chapters devoted to the small-mouth, spotted-bass, and Florida-strain bass. At all times the tactics and theories are geared toward the experienced bass fisherman who is looking to increase the size or quantity of his catch or maybe turn some of those inevitable water-hauls into a more productive or educational experience.—*Gary Miller*

**Fly Tackle**

**by Harmon Henkin. J. B. Lippincott Co., N. Y., N. Y., 1976. 240 p. Illustrated. $9.95.**

"Fly Tackle—A Guide to the Tools of the Trade" is a different kind of book. It is well written, interesting, and the author is knowledgeable about his subject. There is something for everyone; facts, philosophy, and personal opinion. The first one hundred pages are devoted to rods—rod buying and building, a history of rods and rod builders; bamboo, glass, graphite, saltwater, ultralight, and repairs. I do take exception to the prices he quotes for used bamboo rods. I don't think you can find rods in good shape made by the name builders for the prices he quotes. He does indicate used rod prices have fluctuated incredibly recently; I think more incredibly than he is aware. There are three short chapters on gear needed for fishing spring creeks, warm water, and salmon, steelhead and saltwater; I felt the section on steelhead was somewhat weak. Reels, lines, leaders, and all the other paraphernalia used by the fly fisherman are the subjects of additional brief but thoughtful chapters. Appendices list sources of fly fishing tackle, books, and fly tying materials. The illustrations by Jeff Johnson add a great deal to the enjoyment of reading this book.—*K. A. Hashagen, Jr.*

**Classic Rods and Rodmakers**

**by Martin J. Keane; Winchester Press, N. Y., N. Y., 1976; 246 p., illustrated with both color and black and white photos. $15.00.**

It is obvious from the very first page that Martin Keane knows his subject thoroughly and *Classic Rods and Rodmakers* is a labor of love. The material was compiled by digging through old fishing catalogues, patent files, correspondence, and through many personal interviews.

The history of the classic rod is detailed from the earliest days, when rods were made of various woods, through the development of the bamboo rod. Various stages of rod evolution are described (materials, reel seats, ferrules, and guides). The greatest portion of the book describes the lives and works of the great rod makers, explaining, often for the first time, the theory and execution of an individual builder's expertise. The Eastern builders—Leonard, Payne, Orvis, Edward, Gillum, and Garrison are covered comprehensively, as are the middle-American rod builders Dickerson and Young and our well-known western builders E. C. Powell, Walton Powell, R. L. Winston Company, and G. Howells.

I found the book fascinating and educational. The quality of the photographs are the book's only drawback. Frequently they are too small and taken from too great a distance to show the desired detail.—*K. A. Hashagen, Jr.*

**The Essential Fly Tier**

**by J. Edson Leonard; Prentice-Hall, Inc., Englewood Cliffs, N. J., 1976; 262 p., illustrated. $12.95.**

Purportedly, *The Essential Fly Tier* "cuts through the fog of irrelevancies that so often surrounds discussions of the art and science of fly tying." The author, J. Edson Leonard, "discards both the rule book and a host of fly tying myths." In my opinion, however, the book fails to live up to its fly leaf.

Starting with an exhaustive and exhausting discussion of hooks, the book continues with the obligatory chapters on fly tying tools, materials, and fly nomenclature (a glossary of the parts of a fly). The remaining chapters discuss in detail various types of flies for various types of fish (trout, panfish, bass, salmon, steelhead, shad, pike). Line drawings throughout the book illustrate techniques described in the text. Two fold out color plates by the author depict many of the fly patterns described in the text.

I was a bit perplexed by the overall approach of the book. The "fog of irrelevancies" and "discarded rule book and fly tying myths" is more accurately the author's philosophy, which appears

to be to not get too hung up on rules and books, but constantly analyze and do what is necessary to catch fish. I'm not sure for whom—beginner or expert—the book was written. Much of the material in the initial chapter is obviously directed at the beginner. In the chapters on the fly types, however, the descriptions are quite technical and complex and, I'm sure, would be of value to only the advanced tier.

I'd rate this one, at $12.95, as a competent, well written book which contains little new or innovative material.—*K. A. Hashagen, Jr.*

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# INSTRUCTIONS TO AUTHORS

## EDITORIAL POLICY

The editorial staff will consider for publication orginal articles and notes dealing with the conservation of the fauna and flora of California and its adjacent ocean waters. Authors may submit two copies, each, of manuscript, tables, and figures for consideration at any time.

**MANUSCRIPTS:** Authors should refer to the *CBE Style Manual* (third edition) for general guidance in preparing their manuscripts. Some major points are given below.

1. *Typing*—All material submitted, including headings, footnotes, and references must be typewritten double-spaced on white bond paper. Papers shorter than 10 typewritten pages, including tables, should follow the format for notes.
2. *Citations*—All citations should follow the name-and-year system. The "library style" will be followed in listing references.
3. *Abstracts*—Each paper will be introduced by a short, concise abstract. It should immediately follow the title and author's name and be indented at both margins to set it off from the body of the paper.
4. *Abbreviations and numerals*—Use approved abbreviations as listed in the *CBE Style Manual*. In all other cases spell out the entire word.

**TABLES:** Each table should be typewritten double-spaced throughout with the heading centered at the top. Number tables with arabic numerals and place them together in the manuscript following the references. Use only horizontal rules. See a recent issue of *California Fish and Game* for format.

**FIGURES:** Submit figures at least twice final size so they may be reduced for publication. Usable page size is 4⅜ inches by 7⅜ inches. All figures should be tailored to this proportion. Photographs should be submitted on glossy paper with strong contrasts. All figures should be identified with the author's name in the upper left corner and the figure number in the upper right corner. Markings on figures should be in blue pencil or grease pencil, as this color does not reproduce on copyfilm. Figure captions must be typed on a separate sheet headed by the title of the paper and the author's name.

**PROOF AND REPRINTS:** Galley proof will be sent to authors approximately 60 days before publication. Fifty reprints will be provided free of charge to authors. Additional copies may be ordered through the editor at the time the proof is submitted.

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